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Tech Notes

September 1992

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Technology fact sheets from Federal laboratories

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Center for the Utilization of Federal Technology

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Tech Notes

Highlighting Selected U.S. Government Technology & Resources

September 1992

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Published monthly by the National Technical Information Service (NTIS), Tech Notes bring together individual one- to two-page fact sheets prepared by Federal agencies, their laboratories, or contractors. These fact sheets highlight current Federal technology determined to have commercial or practical application. Topics cover new processes, materials, techniques, software, instrumentation, and resources.

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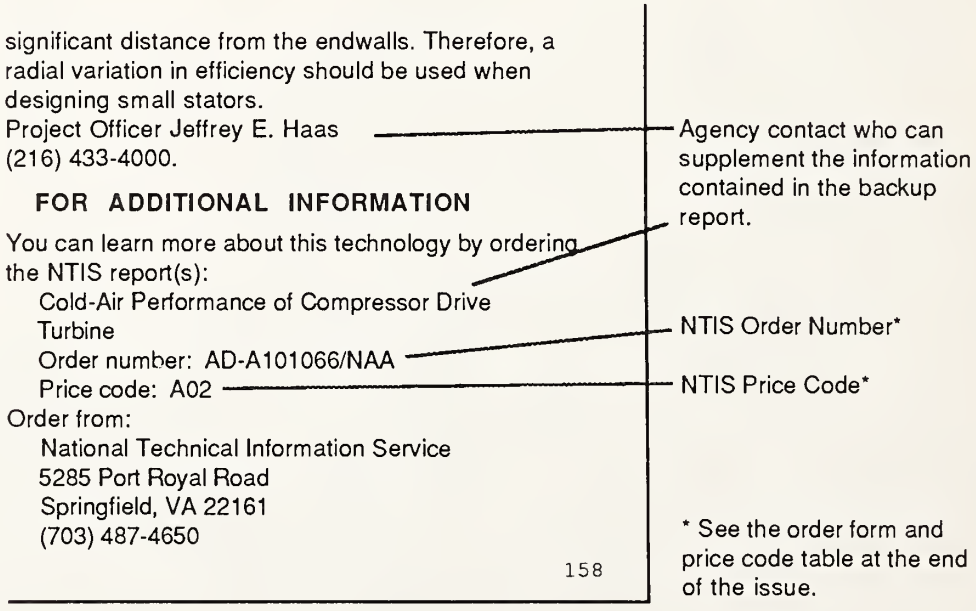
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Project Officer Jeffrey E. Haas
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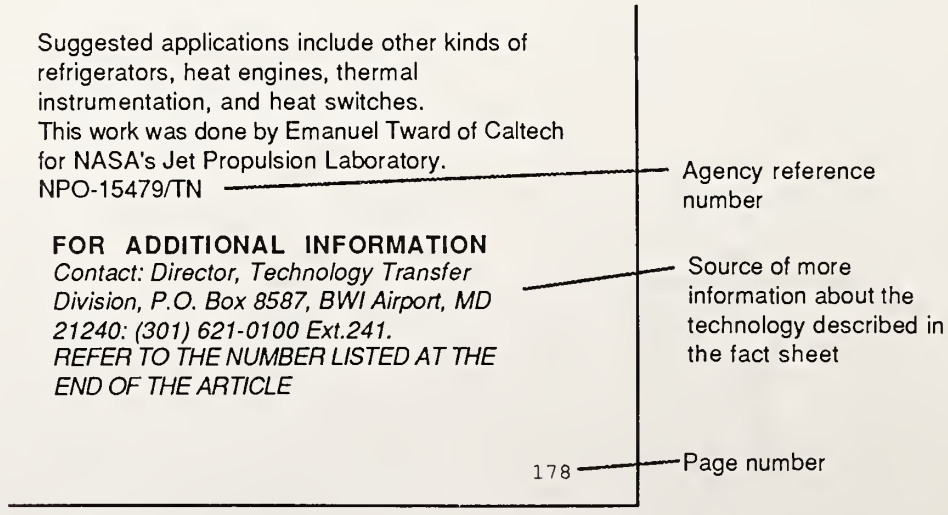
Suggested applications include other kinds of refrigerators, heat engines, thermal instrumentation, and heat switches.
This work was done by Emanuel Tward of Caltech for NASA's Jet Propulsion Laboratory.
NPO-15479/TN
FOR ADDITIONAL INFORMATION
Contact: Director, Technology Transfer Division, P.O. Box 8587, BWI Airport, MD 21240: (301) 621-0100 Ext.241.
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Research Technology
Agricultural Research Service
U.S. Department of Agriculture

Food Flavor Enhanced by Lowering Vegetable Oil Acid

Laboratory "taste tests" have shown lowering levels of an ingredient called linolenic acid in vegetable-based cooking oils improves the taste of food cooked in the oils, a U.S. Department of Agriculture chemist says.

Linolenic acid has long posed a flavor and odor problem to processors of cooking oils from crops such as soybeans and canola, said Timothy L. Mounts of USDA's Agricultural Research Service. The acid can break down over time, causing a fishy flavor and odor when the oil is used for cooking at high temperatures. Also, Mounts said, the threat of deteriorating linolenic acid can limit the shelf life of cooking oils.

To prevent this deterioration, processors have hydrogenated soybean oil, adding hydrogen gas to the oil. The processing industry spends about $200 million a year on hydrogenation, said Mounts.

Mounts said the processing industry could cut hydrogenation costs if linolenic acid levels were reduced. Oils with lower linolenic acid would require much less hydrogenation to ensure freshness.

Iowa State University and a New Jersey company have bred oil plants with lower linolenic acid, Mounts said. Oils from soybeans supplied by ISU and from canola supplied by InterMountain Canola Co. of Cinnaminson, N.J., were used in sensory evaluation tests conducted at the ARS National Center for Agricultural Utilization Research at Peoria, Ill.

"Changing the seeds was the first step," said Mounts. "But the consumer is concerned with the second step, which is to evaluate the effect modified soybeans and canola have on the edible oil product."

Mounts told members of the American Oil Chemists' Society here today that the tests at Peoria showed oils from genetically changed soybean and canola seeds were more stable during high-temperature frying and resulted in better-tasting foods.

In the tests led by food technologist Kathleen L. Warner, tasters noted no fishy flavors in potatoes fried in oils with reduced linolenic acid levels.

The modified soybean oils contained 1.7, 1.9 and 3.5 percent linolenic acid, compared with oil from a standard Hardin soybean variety containing 6.5 percent linolenic acid.

The modified canola oils contained 7.9 and 1.7 percent linolenic acid, compared with a standard canola oil with 10.1 percent linolenic acid. The work was done under a formal cooperative agreement between ARS and InterMountain Canola Co.

FOR ADDITIONAL INFORMATION: Contact for details Timothy L. Mounts, National Center for Agricultural Utilization Research, Agricultural Research Service, USDA, Peoria, Ill. 616704. Telephone: (309) 685-4011.

Research Technology
Agricultural Research Service
U.S. Department of Agriculture

Leaner Chickens Through MRI

Looking at the contour lines on the computer screen, you would never know it was the image of a sleeping chicken or that the image may lead to broiler chickens with leaner meat.

The modern broiler chicken was bred to produce more muscle mass, particularly in the breast, which is the most economically valuable part of the bird. In the process, the chicken became fatter.

Even though chicken is still considered relatively lean, scientists believe it can be made leaner. Chickens have a great deal of fat tied up in a triangular body in the abdomen, "which costs the poultry industry about $500 million annually in waste. Additional fat is found under the skin," says ARS animal scientist Alva D. Mitchell.

Magnetic resonance imaging, or MRI, a handy diagnostic tool for doctors, is making inroads into animal research. MRI can be used to visually dissect living tissue without harming the animal.

"With MRI's three-dimensional cross-sectional images, we can follow the muscle and fat development in a chicken from hatching until it reaches market weight. At the end of the test, the bird will still be around to breed," says Mitchell who does his research at the Non-Ruminant Animal Nutrition Laboratory in Beltsville, Maryland.

The birds are anesthetized to keep them motionless in the test chamber where they are surrounded by a magnetic field. Changes in the field, induced electronically, help differentiate the tissues. An image is displayed on a screen and printed on X-ray film. A series of images can be translated into three-dimensional form, which is displayed on a color computer monitor.

"The images of the various tissues are electronically tinted to better visualize them. On the screen, the image can be moved around to see the tissue from all angles," says Mitchell.

The MRI machine can also be used as a spectrophotometer, an instrument for measuring elements. "In this mode, it is possible to measure total fat and water content of the entire bird," says Mitchell.

Use of MRI in agricultural research is in its infancy. For now, "the practical application of MRI is limited by the expense of the instrument. The small research unit used in these tests cost about a million dollars," says Paul C. Wang of the Department of Radiology, Howard University Hospital, Washington, D.C., who cooperated in the tests conducted at the university's facility.

Alva D. Mitchell is at the USDA-ARS Non-Ruminant Animal Nutrition Laboratory, Beltsville Agricultural Research Center, 10300 Baltimore Ave., Beltsville, MD 20705-2350. Phone (301) 344-2868. ◆

Los Alamos National Laboratory

Sound Reveals Salmonella

Using technology developed to detect chemical or biological weaponry, Los Alamos National Laboratory researchers have demonstrated that sound can identify chicken eggs infected with salmonella bacteria.

"The bottom line is the salmonella bacteria affects how the egg sounds," said Depen Sinha of the Laboratory's Electronics Research Group. "If you had a sensitive enough ear, in principle you could tap the egg with your finger and tell what's going on inside the egg."

There were more than 48,000 reported cases of salmonella poisoning in the United States in 1990, according to the Centers for Disease Control, with many more cases unreported. Infected persons may suffer vomiting, fever and abdominal pains; for persons at risk - pregnant women, infants, the elderly and those with weakened immune systems - the infection can be fatal.

If the Los Alamos findings hold up under further study, an acoustic-based inspection system could provide the egg industry a cheap, portable and quick means to check eggs for salmonella as they roll down the production line.

The Los Alamos researchers used an "acoustic resonance" technique to inspect chicken eggs. They are now looking to apply the technique to the study of bone joint diseases and conditions in the eye. The acoustic resonance technique looks for the natural vibration frequencies, or resonances, of an object.

For their studies, the researchers mounted an egg between two transducers, each about the size of a quarter. One transducer converts an input electrical signal into sound, and the other listens for the sound and converts it back into an electrical signal that can be analyzed. The egg reverberates measurably when the sound matches a natural resonance frequency. The eggshell's natural resonance is affected by conditions in the egg white and yolk. Changes in the viscosity, density and other properties of the egg white and yolk can alter the frequency at which the eggshell resonates.

For eggs artificially inoculated with salmonella bacteria, the researchers detected a second, additional resonance at a higher frequency.

Roger Johnson of the Laboratory's Physical Chemistry/Process Technology Group said, "In our experiments, we were able to detect the salmonella in 25 percent of the infected eggs. We hope to be able to fine-tune our measurements to pull out 100 percent of the infected eggs."

The researchers performed a variety of tests to insure that their salmonella detection was not an artifact of the experimental conditions.

Down on the farm, infected hens lay salmonella-contaminated eggs. There is no way to tell from external inspection if an egg is infected or not. Currently, an egg has to be opened and its egg yolk cultured overnight to determine if it is infected.

"And even if you find salmonella in it, that particular egg is not going to market and will not be eaten," Johnston said.

With the acoustic inspection technique, "We can envision a system that would take only seconds to screen each egg," Johnston said. "It would be very practical and inexpensive to screen every egg."

Johnston cautioned that the acoustic technique needs to be tested on naturally contaminated eggs to demonstrate whether it can detect salmonella in real-world conditions. But, he said, the acoustic technique can probably also be used for other quality-control purposes, such as detecting cracks and other defects in eggshells or spotting double-yolked or fertilized eggs.

The acoustic resonance technology at Los Alamos grew out of arms control treaty verification studies of methods for detecting chemical or biological agents in munitions.

"We are using very much the same type of equipment now to look at eggs," Sinha said. "This is a by-product of defense-related research that has a more direct benefit to society."

The technology offers the same advantages for weapons inspections as it does for egg inspection: The system is compact and portable, requires little electrical power and gives immediate results.

Sinha is studying systems that would use a detached speaker to provide the initial sound input and an optical detector to monitor surface vibrations induced in the object by the sound. This would eliminate any physical contact between the equipment and the object being studied, thus making the technique even faster and more noninvasive.

FOR ADDITIONAL INFORMATION: For more information, contact Dr. Eugene Stark, (505)667-1234.

Computers

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Software

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U.S. Air Force

Wright-Patterson Air Force Base

High Performance Architecture

A High Performance Architecture for Processing Image Algebra Operations, developed by the Air Force Wright Laboratory, Armament Directorate, is extremely fast in handling the natural decomposition of image algebraic functions into their high space bandwidth and point wise operations.

Most processor architectures designed for image processing applications are limited to a specific user function. This architecture, on the other hand, is a data flow concept consisting of three tightly coupled components: a spatial configuration process, a point wise operation process, and an accumulation operation process. Data flow and image processing operations are directed by a control buffer and pipelined to each of the three processing components. The existing algebra is capable of describing all image and signal processing operations. This innovation is notable for how elegantly it handles the natural decomposition of algebraic functions into their high space bandwidth and point wise operations. This means that convolution type operations are computed strictly as a function of the number of elements in the template--not of the number of picture elements in the image. This unique approach is equivalent to "tera-op" performance of conventional, reduced instruction set computer architectures. No other known device or design has made this claim of processing speed and general application to a completely heterogeneous image algebra.

Pending patent approval, this technology will be available for licensing. Benchtop proof of concept is necessary. CRADA opportunity will exist for chip development, advances and customizing.

For further information, contact Jerry Jones, (904) 882-3710. #

Programs Handle PostScript Files

Four programs interpret and format files in the PostScript language.

PSTOOLS is a package of four computer programs that operate on files written in the page-description language, PostScript. The programs include a PostScript previewer for the IRIS workstation, a PostScript driver for the Matrix QCRZ film recorder, a PostScript driver for the Tektronix 4693D printer, and a PostScript code beautifier that formats PostScript files to be more legible.

The three programs PSIRIS, PSMATRIX, and PSTEK are similar in that they all interpret the PostScript language and send out the graphical results to a device. They share common code, which is included as a library of routines. PSPRETTY formats a PostScript file by appropriately indenting procedures and code delimited by "saves" and "restores." PSTOOLS does not use Adobe fonts.

PSTOOLS is written in C language for implementation on SGI IRIS 4D-series workstations running IRIX 3.2 or later. A README file and UNIX manual pages provide information regarding the installation and use of the PSTOOLS programs. A six-page manual that provides slightly more detailed information may be purchased separately. The package of programs is available on a 0.25-in. (6.35-mm) streaming-tape cartridge in UNIX tar format. PSIRIS (the largest program) requires 800K of main memory. PSMATRIX requires the general-purpose interface bus (gpib) circuit board (IEE 488) and the "libgpib.a" library of software, which is available from Silicon Graphics, Inc. The programs with graphical interfaces require that the IRIS have at least 24 bit planes. This package was developed in 1990 and updated in 1991.

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This program was written by Diana Choi and David Yip of **Ames Research Center.** *ARC-12839/TN*

FOR ADDITIONAL INFORMATION

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Electrotechnology

0623 Manufacturing Science For Rugate Filters

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Technology Assessment
U.S. Air Force

Manufacturing Science For Rugate Filters

Achieving the optical performance specifications for advanced military electro-optical systems required conceiving and developing a new class of optical filters called rugate filters. In contrast to multilayer quarter-wave stack filters, rugate filters exhibit exceedingly narrow reflection bands with very high reflectivity and no sidebands, thereby giving high out-of-band transmission. The fabrication of rugate filters required a quantum leap in production technologies used by the thin film optics industry. The objective of this manufacturing science program, which was awarded to Hughes Dansbury Optica in December, 1986, was to facilitate the transition of rugate filter production from the research laboratory to a manufacturing environment.

Completed in March, 1991, this program defined and developed the in-situ optical monitors and process control system to implement a completely closed-loop, real-time feedback system. The baseline deposition process for developing the optical monitoring techniques, scanning photometry, interferometry, and ellipsometry, was ion-assisted physical vapor deposition with e-beam and thermal resistive sources.

Sensor fusion was a key consideration in developing the control system. The control system architecture includes three layers. The lowest layer consists of board-level computers controlling individual optical monitors. This layer is responsible for passing data to the process control computer. The middle layer is responsible for interaction (sensor fusion) of data and process control. The top layer (supervisory) monitors overall system performance, tracks long-term trends, initiates redesign of the rugate filter index profile to correct for production errors, and provides an operator interface.

Expert-system technology enhances the process controller in both the top and lower level controllers. At the supervisory level, the expert system aids in appropriate design selection. With the "Design for Manufacture" philosophy, the expert system assesses the input design and determines the feasibility of the design given the equipment constraints. An alternate design may be suggested. During fabrication, the expert system provides support for trend analysis and can recommend corrective action. At the control level, the expert system adjusts fabrication according to optical monitor inputs as well as status information received from the exception handler which monitors system operational parameters.

The technology developed for rugate filter manufacturing can be applied to other advanced optical coatings. The array of design tools developed enable the prototyping of new coatings with minimum design input. Also, a sophisticated analysis routine was created to enable rapid detection, diagnosis, and repair of deposition failures despite the large volume of data which needed to be interpreted.

FOR ADDITIONAL INFORMATION: To discuss this effort further, contact: Project Engineer: Pamela Schaefer, Air Force Manufacturing Technology Program, ATTN: AFWAL/WL/MLPJ, Wright Patterson AFB, OH 45433-6533; (513)255-3808. Refer to contract: F33615-86-C-5059.

NAVY
Domestic Technology Transfer Fact Sheet

Balloon-like Envelope Used to Transmit Data From Satellite

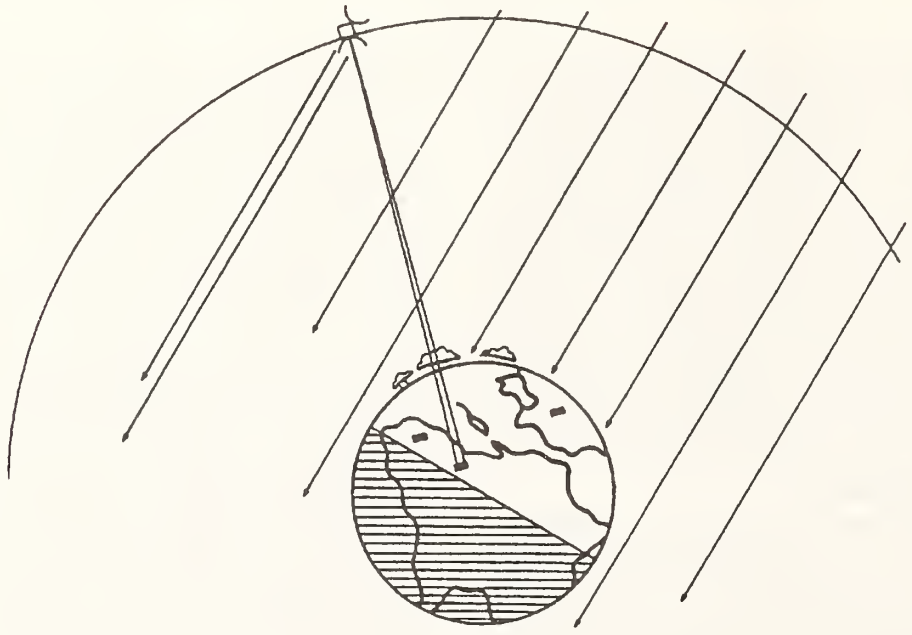


Figure 1. Balloon-like envelope for redirecting the modulated sunlight to a designated area on Earth

A method for broadcasting and optically transmitting data from an orbiting satellite is being developed at the Naval Ocean Systems Center, San Diego, California. The method employs an inflatable ballon-like envelope for receiving and collecting sunlight, a remotely driven modulator for impressing information by modulating received sunlight, and another inflatable balloon-like envelope for redirecting the modulated sunlight to a designated area on Earth (Figure 1). Sequential addressing of spot areas results in a large area broadcast. In addition to using freely available sunlight, the complexity and bulk of the sunlight and redirecting surfaces are greatly reduced to enable the launched deployment of a larger and more effective communication system.

FOR ADDITIONAL INFORMATION: Backup material on this effort is available from: Navy Domestic Technology Fact Sheet Reader Reply Service, Code E211, Naval Surface Weapons Center, Dahlgren, VA 22448-5000; (703)663-8921. Refer to 170101/TN.

Sandia National Laboratory

Methods Allow Making Radar Circuits on Improved Substrates

New methods for making state-of-the-art, high-performance microwave circuits on a soft, flexible substrate have been developed at Sandia National Laboratories.

The innovative techniques could be used by makers of radar systems, avionics electronics, and other systems in which large, high-precision hybrid circuits are needed.

Using these techniques, Sandia researchers accurately patterned and etched circuit conductors, achieving 1/4 mil (a mil is 0.001 of an inch) tolerances and linewidths as narrow as two mils. Features can be machined into the soft substrate with one mil accuracies.

Precision features were needed in the circuits because of the high-frequency requirements of the synthetic aperture radar (SAR) system for which they were developed.

SAR is commonly used for reconnaissance and remote sensing. A SAR system produces higher resolution images of objects than stardard radar in either daylight or darkness and all types of weather conditions. An aircraft moving along a flight path emits continuous microwave pulses that are stored, combined and processed by computer to synthesize a large aperture, which is then focused to produce a detailed terrain image.

In developing the higher frequency SAR, Sandia researchers needed a substrate having a lower dielectric constant to reduce potential losses of the radio frequency signal. They also needed a material that was more forgiving mechanically than the commonly used ceramic to allow them to build larger circuits without the substrate cracking. The circuits, which are up to three times larger than normal hybrid circuits, were needed to accommodate a greater number of functions than are found in other SAR systems. They hybrid circuits used in the SAR system are assembled with a combination of silicon circuits and surface-mounted capacitors and resistors, making them similar to a miniature printed circuit board. While previous radars had five to six smaller microcircuits, the new SAR uses 18 microcircuits.

Sandia researchers chose a commercially available laminate substrate called Duroid™, which required the development of new hybrid circuit fabrication technologies and specialized, high-speed milling techniques.

Duroid™ is a composite material consisting of a ceramic and Teflon™ matrix with a laminated copper sheeting topside (much like a printed circuit board) and a laminated brass backplate, which gives the material the rigidity needed for the fabrication processes.

"In general, we had to produce hybrid circuits with conductors to tolerances we hadn't seen before," says David Norwood of the Hybrid Microcircuit Division. Both the tolerances of the conductor linewidths and their edge definitions had to be precisely controlled to permit high-fidelity electrical operation over large bandwidths.

"The higher the frequency, the more precise your conductor side walls have to be as well as your feature locations," Norwood says.

To accomplish this, researchers had to develop a more accurate method of removing the extraneous copper. They developed a new "spin-spray" etching technique for use with ferric chloride that controls copper removal while the etchant is being sprayed. The technique, which involves spinning the substrate during spraying, had previously been used for semiconductors.

Another innovation was to "overetch" the copper to partially remove it from under the photoresist pattern. This results in straighter conductor side walls, allowing precise definition of where the line meets the substrate. To do that, the resist pattern had to be made slightly wider to compensate for the overetching.

"We're actually controlling the vertical straightness of the line by overetching," Norwood says.

A high-speed, numerically controlled precision machining process was developed to provide the detailed features needed for the hybrid circuits such as relief holes, plated-through holes, and edge cuts. The challenge was to achieve clean, accurate machining through materials with varying hardnesses.

Optimum machining parameters of tool speed, feed rate, tool geometry, and penetration depth were developed using special tungsten carbide-tipped tools, which produced precisely machined features with good surface finishes.

Use of a softer, resilient substrate also required the development of new processes to attach components.

FOR ADDITIONAL INFORMATION: Technical Contacts: David Norwood (505) 845-8084, Richard T. Knudson (505) 844-6209, and Ken Peterson (505) 845-8549, Department of Energy, Sandia National Laboratories, Albuquerque, NM 87185-5800.

U.S. Navy Fact Sheet

Analog VLSI ICs

High speed vector-matrix multiplier operation is the primary operation required for artificial neural networks and many signal processing applications, such as image processing. The Naval Research Laboratory (NRL) has designed and fabricated both 32x32 and 128x64 analog VLSI vector-matrix multiplier circuits and is fabricating a PC computer interface board to operate these circuits. NRL holds the basic patent for capacitive weight storage for vector-matrix multiplier circuits. The advantages of the NRL patent and vector-matrix multiplier circuit approach are

- Conventional VLSI CMOS foundry process
- Extremely high performance: Projected performance of 3 billion multiplications per second for the 128x64 vector-matrix multiplier chip.
- One to two orders-of-magnitude higher performance levels possible using a smaller feature size technology, larger chip size, or multiple chips on a board.
- Fully functional 32x32 vector-matrix multiplier circuits have been demonstrated. (Detailed performance information will be obtained using the PC computer interface board.)

This patented analog VLSI vector-matrix multiplier technology and circuits are available for license and also cooperative research and development agreements (CRADAs) in this technology area of interest. It is envisioned that this patent and circuit technology may be important for neural network accelerator board manufacturers and also integrated circuit vendors. The designed integrated circuit chip layouts would provide a fast entry into this technology area.

For further information, contact Richard H. Rein, (202) 767-3744.

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

$Al_xGa_{1-x}As$ Single-Quantum-Well Surface-Emitting Lasers

Powers and external differential quantum efficiencies exceed those of prior devices configured similarly.

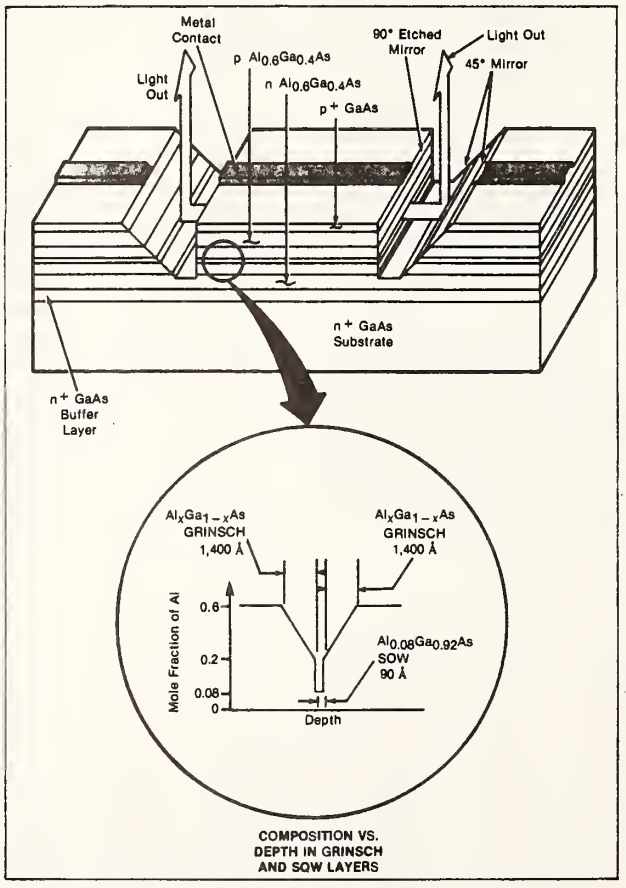
The figure illustrates a surface-emitting solid-state laser that contains an edge-emitting $Al_{0.08}Ga_{0.92}As$ single-quantum-well (SQW) active layer sandwiched between graded-index-of-refraction separate-confinement-heterostructure (GRINSCH) layers of $Al_xGa_{1-x}As$ and that includes etched 90° mirrors and 45° facets to direct the edge-emitted beam perpendicularly to the top surface. The lasers of this type resemble the ones described in the preceding article, "Pseudomorphic-$In_xGa_{1-x}As$ Surface-Emitting Lasers" (NPO-18243), with the principal exception of the distribution of materials in the GRINSCH and SQW layers.

Like the lasers described in the preceding article, these lasers take full advantage of the well-developed edge-emitting Fabry–Perot laser technology. The structures, materials, and processes for the fabrication of lasers of both types are compatible with those of other optoelectronic devices. Consequently, these lasers are suitable for incorporation into optoelectronic integrated circuits for photonic computing; e.g., optoelectronic neural networks.

Prototype lasers like the one shown in the figure were fabricated from a wafer grown by metal-organic vapor-phase epitaxy on a (100) n^+ GaAs substrate with an n^+ GaAs buffer layer. The GaAs and $Al_xGa_{1-x}As$ layers were grown by use of trimethylgallium, trimethylaluminum, and arsine. Sources of p and n doping were diethyl zinc and silane, respectively, in hydrogen. The $Al_{0.08}Ga_{0.92}As$ active layer was 90 Å thick. The two GRINSCH layers, each 1,400 Å thick, were made by linearly grading the mole fraction, x, of AlAs from 0.2 to 0.6. The upper and lower cladding layers were 1.5-μm-thick $Al_{0.6}Ga_{0.4}As$, p- and n-doped, respectively. A cap layer of p^+ GaAs 0.2 μm thick was grown on top to facilitate the formation of an ohmic contact.

The wafer thus produced was subjected to ion-beam etching to produce the 90° Fabry–Perot-mirror surfaces and the 45° output-beam-deflecting mirror surfaces. The mirror surfaces were positioned to define laser cavities ~500 μm long, and the resulting broad surface-emitting lasers were patterned by use of photoresist into laser stripes 100 μm wide. Ohmic metal contacts were then applied.

This Surface-Emitting Solid-State Laser features output power and external differential quantum efficiency greater than those of other GRINSCH SQW lasers with 45° output-beam deflectors.



COMPOSITION VS. DEPTH IN GRINSCH AND SQW LAYERS

In tests, the lasers exhibited a threshold current of 300 mA, a peak output power of 380 mW, and an external differential quantum efficiency of 17 percent without coating of the mirror facets. The threshold current is comparable to, or lower than, previously reported threshold currents, while the output power and external differential quantum efficiency exceed those previously reported for surface-emitting lasers configured similarly. The performance could be improved by decreasing the distance between the 90° and 45° mirror surfaces, by smoothing these surfaces (e.g., by wet chemical and dry etching or by chemically-assisted ion-beam etching), and by applying highly reflective coats to the 45° mirror surfaces.

This work was done by Jae H. Kim of Caltech for **NASA's Jet Propulsion Laboratory**.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA's Resident Office-JPL. Refer to NPO-18281/TN.

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REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Lewis Research Center, Cleveland, Ohio

Channelized-Coplanar-Waveguide PIN-Diode Switches

Isolation exceeds 20 dB, while insertion loss is less than 1 dB.

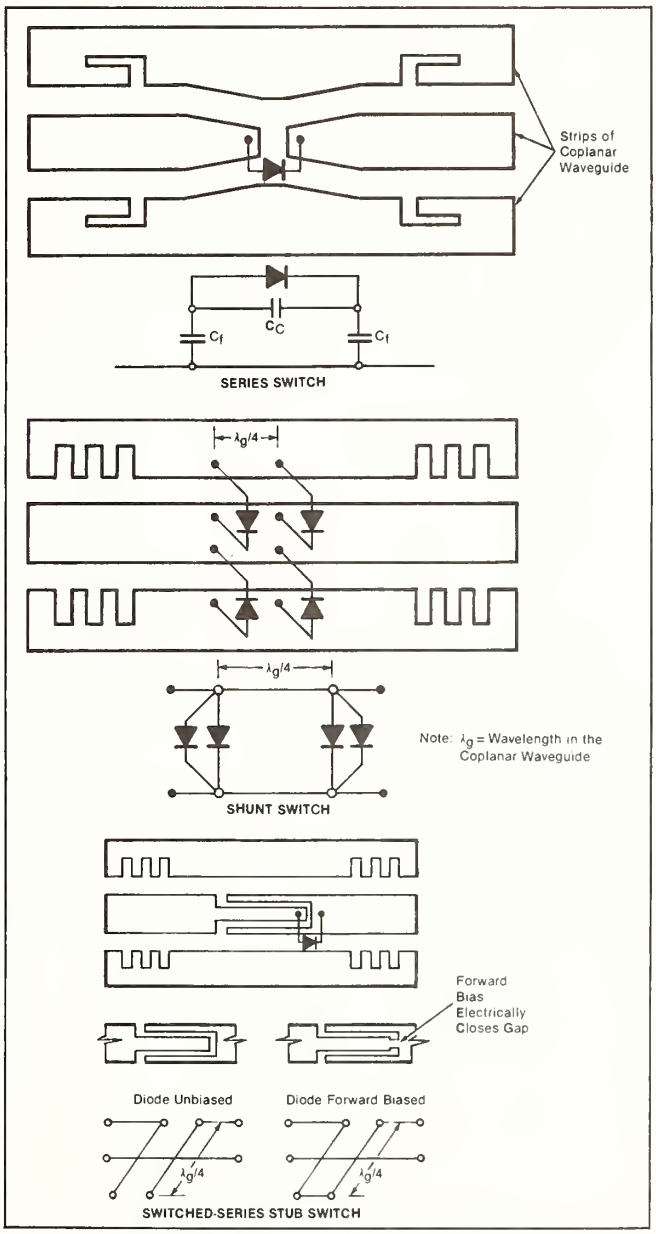
As part of a NASA effort to develop coplanar waveguide (CPW) into a viable alternative to microstrip for microwave and millimeter-wave circuits, three different positive/intrinsic/negative (PIN-diode) reflective CPW switches have been demonstrated. The first switch includes a series-mounted diode to bridge a gap in the center strip conductor of the CPW. The second switch includes a pair of diodes to short the center strip conductor to the ground planes. The third switch includes a diode to switch between a band-pass filter and a notch filter.

The top part of the figure shows the layout and an equivalent electrical circuit of the series-mounted diode switch. The equivalent circuit of the series gap is represented by the capacitive circuit. When the diode is forward biased, the coupling capacitor, C_c, is shorted by the low impedance of the diode, permitting the radio-frequency signal to propagate unattenuated. The isolation of the switch is determined by the high impedance of the reverse-biased diode and C_c. Because the impedance of the coupling capacitor decreases with increasing frequency, the isolation deteriorates at higher frequencies. Therefore, this switch is limited to use at lower frequencies, or else matching circuits must be used to resonate-out the coupling capacitance in the "off" state.

The middle part of the figure illustrates the shunt-mounted diode switch. When the diodes are forward-biased, the slots are loaded by the low impedance of the diode. This low impedance presents an effective short circuit to the radio-frequency signal, which is, therefore, reflected. Additional pairs of diodes spaced a quarter wavelength apart can be used to increase the isolation of the switch.

A switched filter is illustrated at the bottom of the figure. A diode is used to switch between an open-circuit-terminated series stub and a short-circuit-terminated series stub. For a stub one-quarter wavelength long, this is equivalent to switching between a band-pass filter and a notch filter. Because of the high Q (the ratio of reactance to resistance) of the notch filter, very-narrow-band, high-isolation switches can be made.

All three switches have been fabricated with beam-lead PIN diodes and tested. The measured isolation for each switch was greater than 20 dB, and the insertion loss was less than 1 dB.



CPW PIN-Diode Switches have been built in these three configurations.

This work was done by G. E. Ponchak of **Lewis Research Center** *and R. N. Simons of Case Western Reserve University. Further information may be found in NASA TM-102289 [N90-11943], "Channelized Coplanar Waveguide Pin-Diode Switches."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.

LEW-15080/TN

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

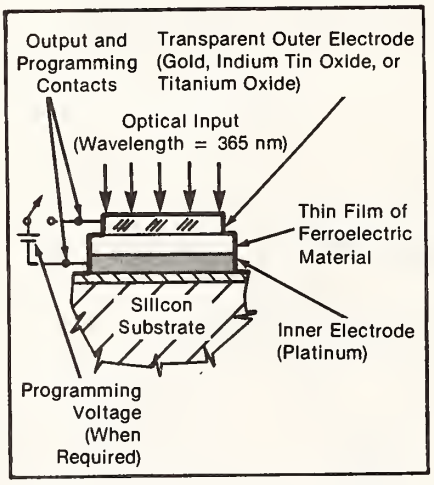
Ferroelectric/Optoelectronic Memory/Processor

A planar memory array would perform massively parallel analog computations.

A proposed hybrid optoelectronic nonvolatile analog memory and data processor would comprise a planar array of microscopic photosensitive ferroelectric capacitors. The processor could perform massively parallel inner-product or matrix•vector computations in real time and at high speed, using optical matrix or vector inputs. Alternatively, the processor could serve as an analog memory array addressable by an optical contactless gate for serial readout. Processors of this type would overcome the electronic crosstalk and the limitations on the number of input/output contacts inherent in electronic implementations of large interconnection arrays. They could be used in general optical computing, recognition of patterns, artificial neural networks, and other applications that require massively parallel input/output operations with ultradense memories.

The processor would be fabricated on a silicon substrate. The microscopic ferroelectric capacitor that constitutes each memory element would include a metal electrode on the substrate, an intermediate layer of ferroelectric material, and a transparent outer electrode (see figure). The remanent electric polarization of the ferroelectric material would be the analog representation of the content of the memory element.

Multiplication or readout of the content would be based on the fact that illumination of a ferroelectric material with photons of energy near its bandgap gives rise to a photocurrent proportional to the product of the remanent polarization and the intensity of the light. The photogenerated charge carriers would move along the internal electric field generated by the remanent polarization, contributing to the overall photocurrent and to the photogenerated electromotive force.


Output and Programming Contacts
Transparent Outer Electrode (Gold, Indium Tin Oxide, or Titanium Oxide)
Optical Input (Wavelength = 365 nm)
Thin Film of Ferroelectric Material
Silicon Substrate
Inner Electrode (Platinum)
Programming Voltage (When Required)

A Photosensitive Ferroelectric Memory Element would put out a current proportional to the optical input and to the remanent polarization of the ferroelectric material. An array of such elements would constitute an ultradense memory and optoelectronic processor.

Suppose, for example, that each element of memory represents one element of a pattern. The remembered pattern could be compared with the illuminating pattern by summing the outputs of all the elements, thereby effectively taking the inner product of the two patterns. As an example of another mode of operation, one could illuminate the array with a pattern that represents a column vector and obtain a matrix•vector product by summing the output currents of the elements in each row.

Each memory element could be programmed with the desired remanent polarization by applying a voltage for a specific time. Typically, for a programming voltage of < 5 V, the programming time would range from 100 ns to 1 ms, depending on the desired analog level. A dynamic analog resolution of 10 bits should be achievable. Memory elements could be as small as 10 by 10 μm. Output current densities could range from about 0.1 to 10 $\mu A/cm^2$ for incident optical signals from about 0.1 to 10 mW/cm^2.

This work was done by Sarita Thakoor and Anilkumar P. Thakoor of Caltech for **NASA's Jet Propulsion Laboratory.**

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to NPO-18222/TN.

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NASA Tech Brief
National Aeronautics and Space Administration
Goddard Space Flight Center, Greenbelt, Maryland

"Forback" dc-to-dc Converters

Features of older converter circuits are combined to obtain advantages and eliminate disadvantages.

Dc-to-dc power-converter circuits of a configuration called "forback" resemble circuits of standard configurations called "forward," "flyback," and "Cúk" (see Figure 1). The forback circuit, which employs minor modifications to existing topologies, combines some of the advantages, while eliminating some of the disadvantages, of the older circuits.

The unique features of the forback configuration are best explained by reference to the isolated version illustrated in Figure 2. As in the Cúk circuit, the secondary winding of the transformer is coupled capacitively to the rectifier and filter circuit. As in the forward circuit, energy is delivered to the secondary while the switching transistor is in the conducting portion of the operating cycle. As in the flyback circuit, energy that is stored in the core of the transformer during the transistor-conduction period is released to a capacitor during the transistor-nonconduction period. Thus, energy is transmitted to the secondary side of the transformer during both the transistor-conduction and the transistor-nonconduction periods of the operating cycle.

The relationships among voltages and currents in the forback configuration are such as to enforce volt-second balance on the core of the transformer. Although the portion of the forback circuit on the primary side of the transformer is similar to that of the forward circuit, the flyback arrangement of the capacitively coupled secondary winding eliminates the need for the reset winding that is used in the forward circuit to return energy stored in the core to the primary side. The voltage stresses on the switching transistor of the forback are less than those in a similar Cúk circuit that includes the same capacitively coupled network on the secondary side of the transformer.

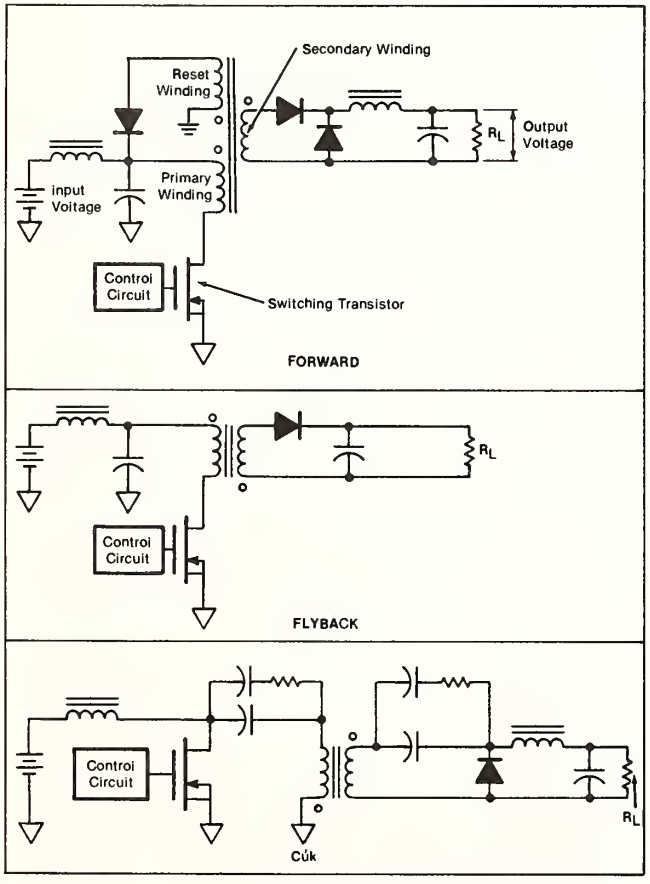

Figure 1. These **dc-to-dc Converter Circuits** are the predecessors of the forback circuit.

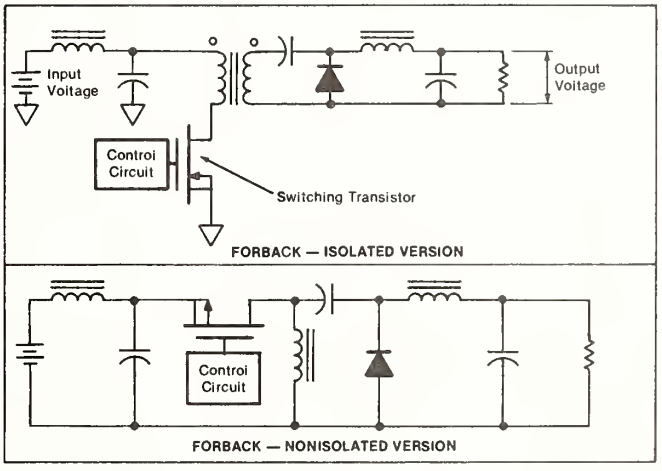

Figure 2. The **Forback Circuit** contains numbers and types of components similar to those of its predecessors. In addition to the isolated version discussed din the text, there is also a nonisolated version.

This work was done by Alan T. Lukemire of **Goddard Space Flight Center.** *GSC-13404/TN*

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Improvements in Processing and Aiming for Squint-Mode SAR

Techniques reduce Doppler drift and accommodate large range walk.

An improved technique for aiming the antenna of a synthetic-aperture radar (SAR) operating in the squint imaging mode (SIM) complements an improved algorithm for processing the raw SIM SAR data. These techniques were developed to reduce the deleterious effects of two unique characteristics of SIM SAR: large range walk and large variation of the Doppler centroid as a function of range.

Range walk is defined as the difference between the ranges (distances) to a point target when the target enters and when it leaves the illuminating radar beam. A large range walk is undesirable because it causes significant dispersion of the point-target response in range if the standard frequency-domain range-and-Doppler-processing algorithm is employed for the azimuth compression. A large variation of the Doppler centroid with range is undesirable because it necessitates an increase in the rate of updating the azimuth-reference function that is used in processing the raw SAR data.

The improved technique for aiming is based on the assumption that the yaw, pitch, and roll angles of the vehicle (a spacecraft in the original application, but presumably also an aircraft) carrying the SAR are known, that the yaw and pitch of the vehicle are controllable, and that the antenna is electronically steerable in tilt about the roll axis of the vehicle. The technique involves a specification of adjustments of the yaw, pitch, and tilt (see Figure 1) that orient the boresight of the antenna such that the Doppler centroid line (the long axis of the area on the ground illuminated by the radar beam) is aligned with the iso-Doppler lines. This alignment reduces the variations in the Doppler centroid, thereby simplifying the processing of the raw SAR data.

The improved algorithm for processing the SAR data is a modified version of the standard frequency-domain range-and-Doppler-processing algorithm, which results in significant degradation of the point-target response at squint angles greater than 8°. The improved algorithm includes an additional step in which a secondary range-reference function used to process the raw SAR data in the range-and-Doppler domain is updated according to the change in the Doppler frequency across the azimuth spectrum; that is, a number of secondary range-reference functions based on different Doppler frequencies are generated.

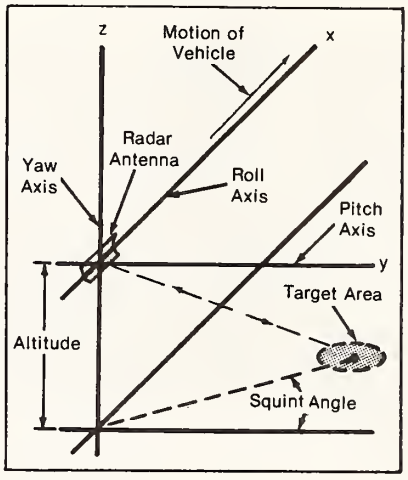

Figure 1. Selected Aspects of the SAR Geometry are illustrated to define terms used in the text.

In the improved algorithm (see Figure 2), the dispersed range impulse is compressed in the range-and-Doppler domain after the azimuth fast Fourier transform (FFT). The same range chirp rate is used in the range compression as is used in processing data in the broadside imaging mode. After the range-reference multiplication, the data are "corner-turned" to make them accessible in the azimuth direction. The azimuth FFT is applied for each azimuth line and is followed by a second corner turn so that the data can be again read in the range direction. Then the secondary range compression is applied. Secondary range-reference functions are generated for a number of frequencies in the azimuth spectrum. Each range line is multiplied with the corresponding secondary range-reference function (to compress the dispersed range impulse response), and then an inverse range FFT is applied. The data are then corner-turned for easy access in the azimuth dimension. The range-migration correction is made and is followed by azimuth-reference multiplication and inverse azimuth FFT. This completes the SAR image-formation process.

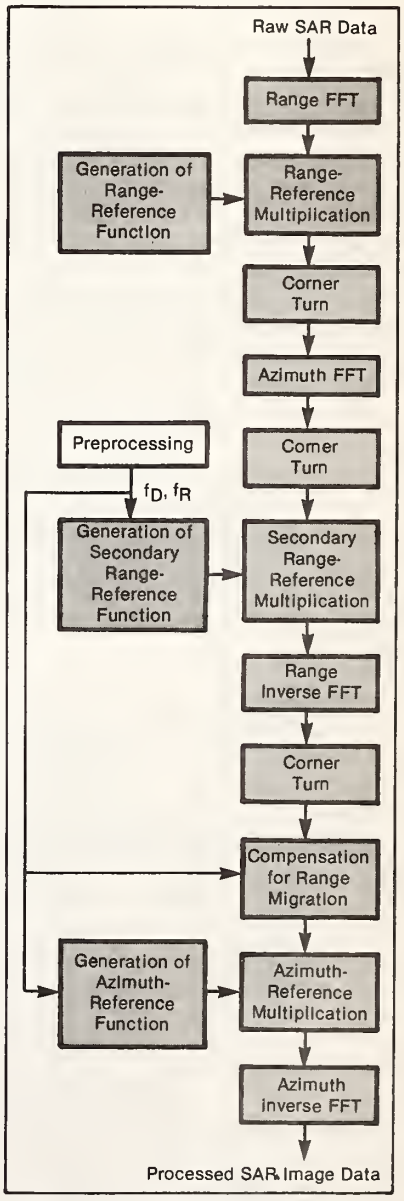

Figure 2. The Squint-Imaging-Mode Processing Algorithm includes a secondary range compression in the range-and-Doppler domain.

This work was done by Chi Y. Chang, Michael Y. Jin, and John C. Curlander of Caltech for **NASA's Jet Propulsion Laboratory.** *NPO-17908/TN*

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

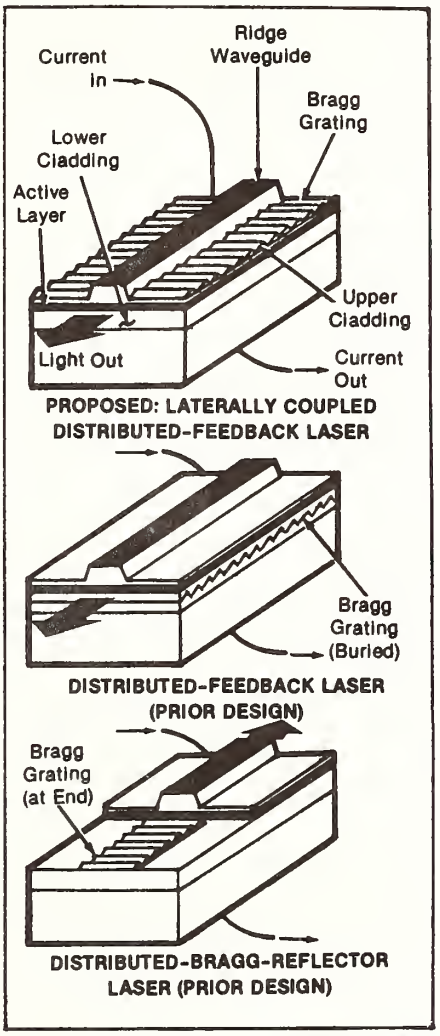
Laterally Coupled Distributed-Feedback Lasers

Gratings would be located laterally (instead of longitudinally) next to ridge waveguides.

Distributed-feedback semiconductor lasers of a proposed design called "laterally coupled" would feature Bragg gratings located on the top surfaces next to the sides of the ridge waveguides that overlie the gain regions of the laser resonators. The figure shows a proposed laterally coupled distributed-feedback laser along with (1) a distributed-feedback laser of prior design in which the Bragg grating is located underneath the ridge waveguide, and (2) a laser of related prior design called "distributed Bragg reflector," in which the Bragg reflector is located at one end of the ridge waveguide.

Both of the prior designs involve disadvantages. Distributed-Bragg-grating lasers have more-complicated shapes, and, therefore, more steps are needed to fabricate them. The fabrication of distributed-feedback lasers is simpler, but undesirable scattering occurs at the discontinuities between the Bragg gratings and the overlying layers of the laser structures.

In comparison with the devices of both prior designs, the proposed laterally coupled devices could be fabricated in fewer steps. The scattering would also be suppressed. In a laterally coupled distributed-feedback laser, the gratings would interact with the lateral evanescent electromagnetic fields, producing the feedback that would support oscillation in a single mode.



A Laterally Coupled Distributed-Feedback Laser offers advantages over lasers of two related prior designs.

By etching the ridge waveguide and grating separately, precise control over the grating depth is achieved, yielding precise control over the amount of grating coupling. A single-mode laterally coupled DFB laser has been demonstrated operating single-mode at 9054 Å wavelength based on this structure.

This work was done by Robert J. Lang and Siamak Forouhar of Caltech, and Richard C. Tiberio and George Porkolab of Cornell University for **NASA's Jet Propulsion Laboratory.**

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office-JPL. Refer to NPO-18393/TN.

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Infrared Multiple-Quantum-Well Phototransistor

Photocurrent would be amplified, and dark current would be suppressed.

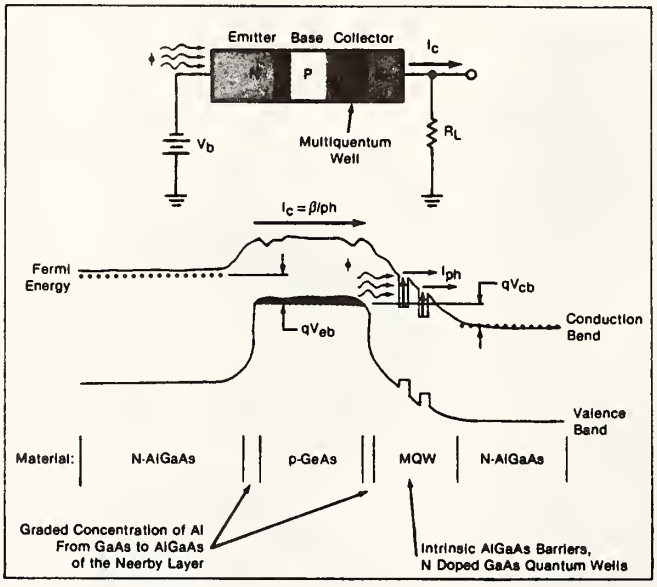
A proposed npn $Al_xGa_{1-x}As$ phototransistor would incorporate a multiple-quantum-well (MQW) infrared photodetector. This internal MQW photodetector would have n-doped contacts and would be embedded between the p-doped base region and the n-doped collector region of the transistor (see figure). The heterostructure of the transistor would be such that the gap between the valence and conduction electron-energy bands would be greater in the emitter than in the base. As a consequence, the electric field at the junction between the emitter and the base would block the hole current, thereby reducing the dark current. Moreover, the quantum-well barriers would be made relatively thick to reduce quantum tunneling between the quantum wells, thereby reducing the dark current further.

The incident radiation would excite electrons in the base/collector junction. The resulting change in the charge of the base would alter the potential across the base/emitter junction, causing the emitter to inject electrons into the base. Provided that the lifetime of the injected electrons in the base exceeded the time of transit of these electrons across the base, normal transistor action would produce current gain. With an applied bias and the base contact floating, the photogenerated carriers would contribute a photocurrent I_{ph} in the collector. The total collector current, I_c, would be given by

$$I_c = (1+\beta)I_{ph}$$

where the transistor gain, β, would be of the order of 100.

By making the MQW long (preferably at least one characteristic length for the absorption of photons of the wavelength of interest), it would increase the quantum detection efficiency. It would allow the base region to be kept small — a requirement for achieving high transistor gain. The high electric field in the collector/base junction portion of the MQW region would rapidly sweep the photoexcited electrons from the junction, increasing the response. The coupling of radiation to the phototransistor could be enhanced by directing the radiation along the MQW detector with a diffraction grating or other device to match the selection rule of the intersubband transitions in the quantum wells.



The $Al_xGa_{1-x}As$ **Infrared Phototransistor** would include a multiple-quantum-well detector in its base/collector region.

This work was done by Shmuel I. Borenstain of Caltech for **NASA's Jet Propulsion Laboratory**.
NPO-17980/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

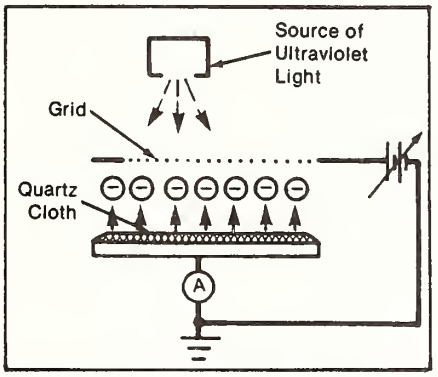
Lightweight, High-Yield Photocathode

Quartz cloth multiplies electron current.

A layer of Astroquartz (or equivalent) cloth woven from quartz thread is an essential part of a high-yield photocathode. Such a photocathode is desirable in applications in which low power consumption is required.

In an experiment (see figure), a piece of Astroquartz material with an aluminum backing was placed on a grounded metallic plate. The aluminum backing was in direct electrical contact with the metallic plate and thus also at ground potential. A positively biased wire-mesh grid was placed 1 cm above the quartz cloth, resulting in a strong electric field in the region between the grid and the cloth.

When the cloth was illuminated with ultraviolet light (to which the quartz cloth was semitransparent), photoelectrons were produced at the aluminum backing surface. The photoelectrons were accelerated by the electric field. When the high-energy electrons collided with the quartz cloth, electron multiplication occurred via the generation of secondary electrons at the surface of the cloth. These secondary electrons were accelerated by the strong electric field and were ejected into space.



Quartz Cloth Multiplies the Electron Current emitted by an aluminum photocathode sensitive to ultraviolet light when placed in an external steady-state electric field.

In the experiment, the ratio between the total current emitted from the aluminum surface covered by the quartz cloth and the current emitted by the aluminum surface alone was measured at various applied voltages. For example, at a potential of 2.0 kV, the total current emitted from the surface covered by quartz cloth was 2.66 times as large; at 4.0 kV, it was 667 times as large.

This work was done by Philip L. Leung and Stephen B. Gabriel of Caltech and Ralph F. Wuerker of the University of California at Los Angeles for **NASA's Jet Propulsion Laboratory.**
NPO-18226/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Optical Phase-Locked Loop for Optical Communication

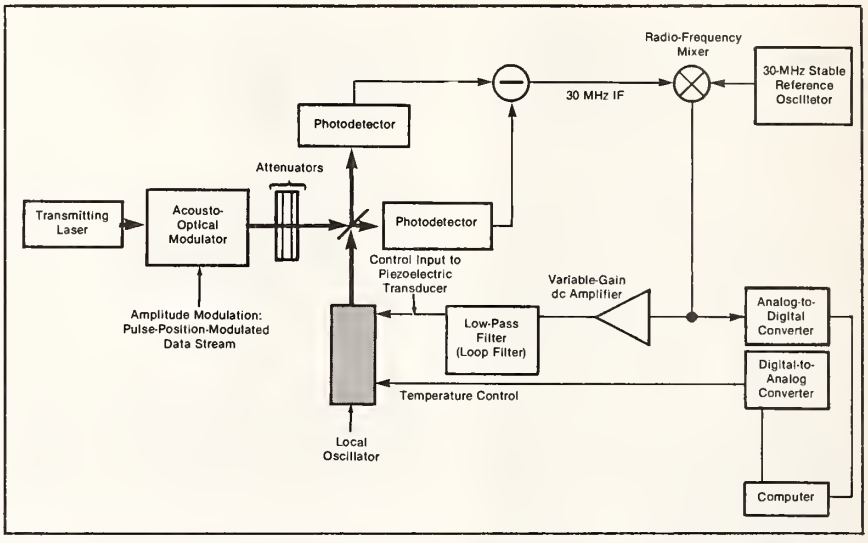
Phase-error variance of less than 0.05 mrad^2 is achieved with a relatively-narrow-band loop.

Tracking of the phase of a laser beam has been demonstrated with an experimental optical phase-locked loop of narrower bandwidth than has been used before. Potential applications for optical phase-locked loops include free-space and fiber-optic communications, navigation, and scientific instrumentation in which receivers may be required to track the phases of transmitted signals.

Heretofore, coherent optical communication systems have been based on diode lasers (as distinguished from diode-pumped solid-state lasers). Because of the broad spectra emitted by diode lasers, typical coherent phase-tracking loops that contain diode-laser oscillators must have bandwidths of several megahertz — too wide for use in deep-space communication or wherever else received signals may be weak. Recently developed diode-pumped solid-state lasers emit spectra of subkilohertz width, enabling the use of receiver phase-tracking loops that have bandwidths of only a few kilohertz.

The experimental apparatus (see figure) includes two diode-pumped solid-state lasers of the non-planar-ring-oscillator type, one of which represents the transmitting (tracked) oscillator, the other of which represents the local oscillator in a receiver (the tracking oscillator). The output of the transmitting oscillator is amplitude-modulated with a pulse-position-modulated data stream.

The transmitted signal is attenuated and combined in a beam splitter with the local-oscillator signal, and the two signals are detected using balance-detector configuration to an IF frequency of 30 MHz. The difference between the outputs of the photodetectors is mixed with the 30-MHz output of a stable reference oscillator to obtain a raw baseband signal. The raw baseband signal is processed through a variable-gain dc amplifier to obtain an error signal. The error signal is low-pass-filtered and fed to a piezoelectric transducer that adjusts the frequency of the local oscillator.



This Optical Phase-Locked Loop exhibits a phase-error variance of 5×10^{-5} rad^2 at a closed-loop bandwidth of 20 kHz.

The piezoelectric transducer operates rapidly enough to track the instantaneous phase within a narrow range: its tuning range is not wide enough to enable it to compensate for large, slow drifts in lasing frequency. Consequently, a frequency-compensation loop must be included to maintain the piezoelectric transducer at the center of its dynamic range. This is accomplished by applying a small bias signal at the temperature controller of the local-oscillator laser. The bandwidth or the update rate of the temperature controller is usually limited to less than 10 Hz because temperature control is inherently slow.

When the loop is in lock, any difference between the frequencies or phases of the two laser oscillators results in a dc signal at the output of the radio-frequency mixer, which functions as a phase comparator. Temperature control is accomplished by sampling the output of the phase comparator and applying the proper compensating signal at the temperature-control input.

The results of the phase-locking experiment indicate that at a closed-loop bandwidth of 20 kHz, the phase-error variance is only 5×10^{-5} rad^2. At and above this closed-loop bandwidth, the laser spectrum resembles that of an oscillator that has a white frequency noise with an instantaneous spectral width of 0.2 Hz.

This work was done by Moe Z. Win, Chien C. Chen, James R. Lesh, William K. Marshall, and Marc D. Rayman of Caltech and Robert A. Scholtz of the Univeristy of Southern California for **NASA's Jet Propulsion Laboratory.**
NPO-18200/TN

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Sandia National Laboratory

Technique Advances Measurement of Superconductors

A novel technique representing a major advance in measuring a crucial property of the new high-temperature superconducting materials has been developed at Sandia National Laboratories.

It has so many advantages over present methods for making the measurement that its developers say it may be an "enabling technology" for the emerging high-temperature superconductor industry.

The technique is already being used for routine analysis of superconductors at Sandia, and it could quickly reach industry: Sandia and a private company, Conductus, Inc., of Sunnyvale, California, have developed a manufacturable prototype version, and initial orders have been received.

Although the technique's expected primary use is for superconductors, it is equally useful for evaluating thin-film and bulk conductors intended for high-speed circuits and microwave applications. With some additions, it can also be used to evaluate chemical reactions in either liquid or gas environments, and that could be a boon for the areas of corrosion, batteries, and environmental monitoring.

Easier measure of surface resistance

A key parameter for determining the quality of conducting or superconducting materials—especially those intended for high speed or microwave electronic applications—is the surface resistance. Surface resistance is difficult to measure by conventional means. The sample usually must be incorporated into a microwave cavity, and this sometimes requires cutting or modifying the sample.

The new technique, developed by Sandia electrical engineers Jon Martens and Vincent Hietala, measures the surface resistance without coming into contact with the sample. Sandia researchers David Ginley and Thomas Zipperian, plus Gert Hohenwarter of the University of Wisconsin-Madison and Parkview Works, Inc., in Milton, Wisconsin, also contributed to the development.

The technique can be used on complex shapes and can spatially scan the sample to provide a two-dimensional image of the surface resistance. Since it is non-contact and portable, it can be readily used in situ—wherever the sample is located—for process monitoring.

Sandia researchers Jon Martens and Vicent Hietala demonstrate their confocal resonator. It is considered a major advance in measuring the surface resistance of high-temperature superconductors and thin-film and bulk conductors. It may have other applications as well.

The device is called a confocal resonator. It uses a quasi-optical microwave resonance technique. The basic instrument employs a resonant cavity formed between a spherical mirror and the conducting sample. When the structure is in resonance, a standing electromagnetic wave exists, and its properties are strongly affected by the detailed dielectric and conductive properties of the materials in its path. The characteristics of this standing wave are then used to deduce the sample's surface resistance.

The instrument can measure the surface resistance of a sample as a function of position and temperature, something critical for superconducting materials. Martens and Hietala point out that it is important to map the surface resistance of a superconducting wafer before expensive and complicated processing is done, both to determine the film quality and locate any defects. They say the technique can be used for *any* thin-film conductor or superconductor in the same way.

May have significant impact

"The evaluation of surface resistance is the key measure of the quality of superconducting materials intended for high-speed signal processing and microwave communication applications," says Martens. "Existing diagnostics were difficult to perform, time consuming, could not provide spatial mapping, and

often required cutting wafers or patterning. The instrument we've developed removes most of these limitations."

"The technique is non-contact, can be used in-situ, it is rapid, can map samples to better than 1 millimeter resolution, and can view a water of virtually any size or shape."

The Sandia researchers add that extensions of the concept may have "significant impact" in the areas of high-energy-density batteries, thin-film growth, corrosion and aging, and the identification of materials defects.

"The confocal resonator represents a significant new analytical instrument, and we are just beginning to explore all its possible applications," Martens says.

FOR ADDITIONAL INFORMATION: Technical Contacts: Jon Martens (505) 844-2226, Vincent Hietala (505) 844-5849, and David Ginley (505) 844-8863, Department of Energy, Sandia National Laboratories, Albuquerque, NM 87185-5800.

Energy

0637 Record Efficiency for Cadmium-Telluride PV Cell

0638 Alternative Heating With Coal

0639 Calculating Pressures in Electrochemical Cells—The initial pressure and void volume strongly affect the subsequent dependence of pressure on temperature.

National Renewable Energy Laboratory

Record Efficiency for Cadmium-Telluride PV Cell

NREL researchers have verified a record 14.6% conversion efficiency for a photovoltaic cell made of cadmium-telluride (CdTe) thin films.

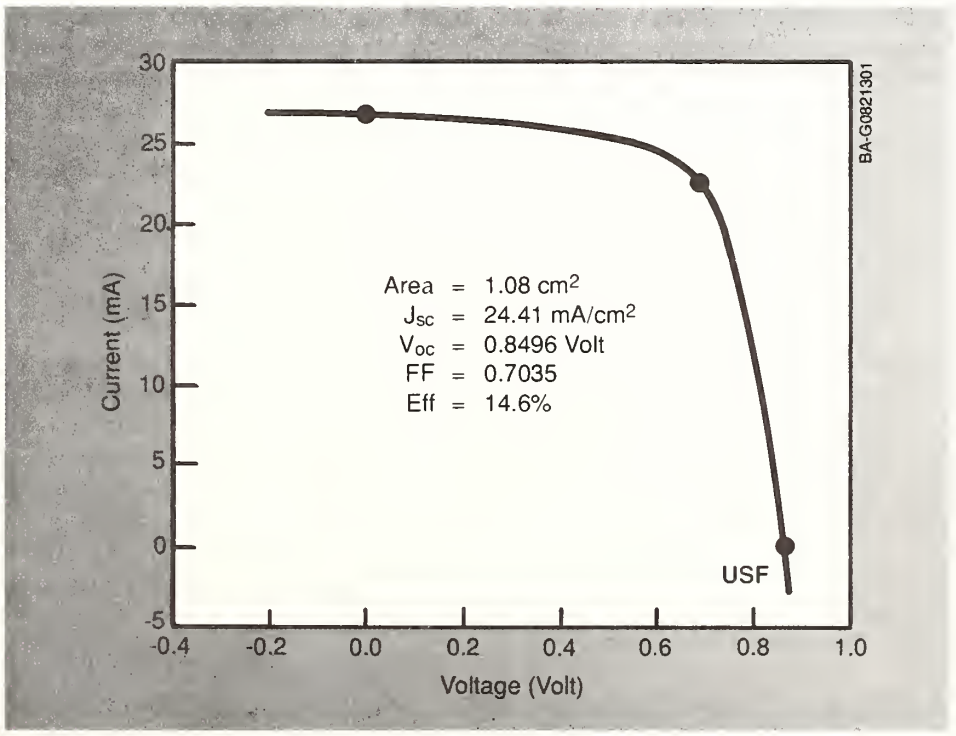
"The fact that this technology has now surpassed all other thin films in efficiency bodes well for its future," said Tom Surek, manager of NREL's photovoltaics program.

The record-breaking cell was fabricated by Professor Ting Chu at the University of South Florida in a collaborative research effort with NREL and Colorado State University (CSU). Chu's research was directly funded by NREL through a three-year subcontract; he received indirect funding as a subcontractor for Photon Energy Inc. of El Paso, Tex., which is participating in the DOE/NREL polycrystalline thin-film initiative.

Chu used an inexpensive technique called close-space sublimation to fabricate the experimental CdTe cell. Optical measurements taken at CSU determined that cell performance could be improved by reducing reflection losses, which occur when sunlight strikes the cell and reflects off the surface. Based on CSU's analysis, NREL scientists applied an anti-reflective coating and boosted the cell's efficiency by almost 10%.

Progress in CdTe technology can also be attributed to Chu's use of solution-grown cadmium sulfide as the heterojunction partner.

Companies such as Photon Energy are in a good position to take advantage of Chu's results. Photon Energy recently began manufacturing four-



Professor Ting Chu, an NREL subcontractor, recently achieved a record 14.6% conversion efficiency with his innovative cadmium-telluride PV cell.

square-foot CdTe modules with a prototype production line. NREL researchers confirmed a 6.4% aperture-area efficiency for one of these devices in outdoor tests; power output was 21.3 watts, the highest known output from a CdTe module to date. Chu's results indicate that CdTe has the potential for modules with efficiencies of up to 15%.

Chu is retiring from his university position but will serve as a consultant to NREL researchers as they continue his work in CdTe technology.

For Additional Information:

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Refer to Volume XIV, Number 1/TN

U.S. Navy Technology Application

Naval Civil Engineering Laboratory

Alternative Heating With Coal

The Naval Civil Engineering Laboratory has developed a unique coal burning device, the Annular Vortex Combustor, or AVC, to fuel small- to medium-size boilers of the kind most often used to heat residences, apartment and office buildings, and for light industry and commercial applications.

Simplicity of construction, low emissions and high efficiency characteristics of the AVC enable coal, America's most abundant energy resource, to enter the boiler-fuel market as a practical alternative to heating-oil dependency, with its history of threatened shortages and price fluctuations in some parts of the country.

A sequence of exploratory and preliminary subscale model tests preceded construction of a proof-of-concept AVC model, which demonstrated highly efficient boiler operation, using Dry Ultrafine Coal (DUC), utility-grind Pulverized Coal (PC) and Coal-Water Fuel (CWF).

Results of the AVC tests indicate:

- Ideal for operation in a wide range of boiler-firing operations (tested range: 0.1 - 30 million Btu/hr)
- High (99%) combustion efficiency
- High average firing intensity, enabling compact AVC design
- No pre-heating requirements
- Fast start-up; approximately 15 minutes from ignition to full load
- Turndown capability on the order of 3:1
- Low temperature operations (1660 - 2200 degrees F), resulting in low emissions and maintenance costs and high reliability
- Controllable combustion environment and particle movement to ensure complete fuel burnout.

The Naval Civil Engineering Laboratory is seeking licensees for this technology. This may be through direct licensing or cooperative research and development agreements. Interested parties should contact Jerry Dummer, (805) 982-1599.

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Calculating Pressures in Electrochemical Cells

The initial pressure and void volume strongly affect the subsequent dependence of pressure on temperature.

A semiempirical method provides for the calculation of operating conditions in electrochemical storage cells equipped with pressure-relief vents. Conceived for use with Li/$SOCl_2$ cells, the method should also be applicable to other electrochemical cells in which the interdependence of pressure, temperature, and state of charge is a design issue.

The vent in an Li/$SOCl_2$ cell is intended to open before the pressure rises to a dangerously high value at the expected operating temperatures. The semiempirical method is used to design a cell to discharge both safely and completely, without reaching the designated venting pressure (which is below the maximum safe pressure).

According to the method, the total pressure in a cell is taken to be the sum of the vapor pressure of the electrolyte and the pressure of the inert gas (argon) that initially fills the void volume above the electrolyte. For this purpose the vapor pressure of the electrolyte as a function of temperature is measured in a cell in the fully charged and fully discharged states. An interpolation is performed for states of intermediate charge (see figure). The pressure of the inert gas as a function of temperature is determined from the initial and final temperatures and volumes of the inert gas, by use of the ideal-gas law. For this purpose, the final volume of the inert gas is estimated from the initial void volume, the decrease in void volume resulting from the thermal expansion of the electrolyte, the decrease in void volume resulting from the formation of end products, and the increase in void volume resulting from the consumption of starting materials.

Pressure-vs.-temperature-vs.-state-of-discharge calculations were performed in an application of this method to two commercial Li/$SOCl_2$ cells: a Honeywell 250-Ah cell and a Whittaker–Yardney 250-Ah cell. The following conclusions were drawn from these calculations:

- The cells exhibit a spread in temperatures that correspond to a given venting pressure.
- The spread in temperatures is diminished as the initial pressure of the inert gas increases.
- The temperature required to produce a given pressure increases with an increase in void volume.
- Suitable venting pressures for the Honeywell and Whittaker–Yardney cells with initial void volumes of 112 mL are in the ranges of 250 to 300 psi (1.7 to 2.1 MPa) and 200 to 500 psi (1.4 to 3.4 MPa), respectively, with initial inert-gas pressures of 15 to 40 psi (100 to 280 kPa) and 40 psi (280 kPa), respectively.

The Electrolyte-Vapor Pressure in a commercial Li/$SOCl_2$ cell was measured at various temperatures at full charge and full discharge. The full-discharge data were then extrapolated to unmeasured values. Finally, interpolations were made to states of 25, 50, and 75 percent of full charge. The solid portions of the curves indicate experimental data; the dashed portions represent extrapolations and interpolations.

This work was done by Ralph Lutwack, Harvey A. Frank, and Alan I. Attia of Caltech for **NASA's Jet Propulsion Laboratory**. *NPO-18078/TN*

Engineering

0640 Expert System for Determining the Spontaneous Combustion Potential of Coal

0641 Highwall Coal Mining is Controlled From Station on Bench

0642 First Hologram Made of Hypervelocity Impact at 4.2 km/sec

0643 'Touch' Added to New Keyboard

0644 Bilevel Shared Control of a Remote Robotic Manipulator—Teleoperator and autonomous modes would be blended, each overcoming deficiencies of the other. (Licensing Opportunity)

0645 Electrochemical System Would Supply O2, H2O, N2, and H2—Atmospheric gases would be stored in propellant rather than compressed.

Software

0646 PC-Based Program for Air-Stripper Design and Costing (ASDC)

0647 Designing Assemblies of Plates—VICONOPT facilitates design and analysis with respect to buckling and vibrations.

Testing & Instrumentation

0648 Remotely Operated Vehicle

0649 Nondestructive Inspection of Large Structural Components

0650 Predictive Monitoring With Many Sensors—A few sensors would be selected according to the state of the monitored system.

New Technology from the U.S. Bureau of Mines

U.S. Department of the Interior

Expert System for Determining the Spontaneous Combustion Potential of Coal

Objective

Predict the spontaneous combustion potential of a coal using an expert system computer program.

Background

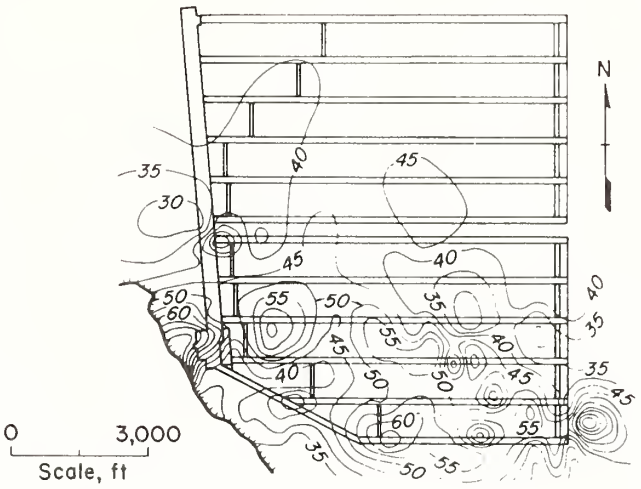
Approximately 15% of underground coal mine fires in the United States are attributed to spontaneous combustion. These spontaneous combustion fires frequently occur in worked-out or abandoned areas of a coal mine. This makes the control and extinguishment of the fire difficult and often requires large sections of the mine or even the entire mine to be sealed for long periods of time. A prior knowledge of the self-heating potential of the coal can be useful in preventing spontaneous combustion fires through the use of aggressive monitoring and control measures at existing coal mining operations, and in the planning of new mines.

Many factors can affect the spontaneous combustion process in a mine, including the self-heating potential of the coal, ventilation, geologic factors, and mining conditions and practices. Various test methods have been used to evaluate the relative self-heating potential of coals, including crossing point temperature and adiabatic heating methods, and oxygen adsorption techniques. However, these tests are usually time-consuming and difficult to conduct, limiting their use to laboratories.

An adiabatic heating test has been used extensively by the Bureau of Mines to examine the self-heating potentials of coals. A ranking scheme was established to assess a coal's relative self-heating potential, based on the coal's minimum self-heating temperature (SHT). SHT is the minimum initial temperature from which a coal undergoes a sustained exothermic reaction in the adiabatic oven. Coals that have a minimum SHT < 70° C are considered to have a high spontaneous combustion potential; those with minimum SHT's between 70° and 100° C are a medium risk, and coals with minimum SHT's > 100° C have a low spontaneous combustion potential. However, like other methods, this test is time consuming and difficult to conduct.

A statistical analysis of the adiabatic oven results for coals showed that the minimum SHT of a bituminous coal was strongly dependent on its dry ash-free (DAF) oxygen content, a value readily obtainable from a routine ultimate analysis, by the expression:

$$SHT_{min}, °C = 139.7 - 6.6 \times [\text{Oxygen, pct (DAF)}].$$



Self-heating temperature (°C) isotherm map of a proposed mine using predicted self-heating temperature values from borehole samples.

Thus a bituminous coal's relative self-heating potential could be determined by a simple empirical expression without the need for detailed and costly experiments.

Approach

The results of the adiabatic heating tests were incorporated into an expert system computer program. An expert system is a computer program that uses available information to make decisions based on a series of rules provided by the programmer. It is an interactive, user-friendly, and inexpensive method of conveying "expert" advice. In this case, the advice is about the self-heating potential of a coal sample, and requires only the input of data from a typical coal analysis. The program was designed to allow direct entry of data for a single sample or from an existing database.

How It Works

The program requires the input of the coal's proximate and ultimate analyses and heating value. The program allows for the direct entry of sample data from the keyboard, or more typically for a mining operation, from an existing database. The program is compatible with several standard database programs. However, the program's ac-

cess to a database requires that the existing database structure must match that required by the expert system program. Detailed instructions are included in the program to accomplish this.

If an existing database of coal analyses is available, the user has the option of analyzing the self-heating potential of a single sample in the database, a range of specified samples, or the entire database. The results are then stored in the database, and can be viewed, edited, or printed out using the program's browse or report functions.

The basis of the expert system is the empirical expression that predicts the minimum SHT, and the relative risk assignment based on the predicted SHT. However, this expression was found to be valid only for bituminous coals. Thus, the system first determines the rank of the coal sample. If the rank is bituminous, the risk is assigned based on the predicted SHT. If the predicted SHT is < 70° C, the sample is assigned a high spontaneous combustion potential. If the SHT is between 70° and 100° C, a medium potential, and if the SHT is > 100° C, the sample is assigned a low spontaneous combustion potential.

If the rank is determined to be lignite or subbituminous, the coal is assigned a high self-heating potential. If the rank is anthracite, the sample is assigned a low self-heating potential. These assignments were based on laboratory results showing, in general, that subbituminous and lignite coals had minimum SHT's that fell in the high self-heating category, while anthracite coals showed very low self-heating potentials.

The use of the expert system allows the assignment of the self-heating potential of a coal sample without the need for laboratory experiments. The program, however, evaluates only the relative self-heating potential of the sample, and does not take into account other important factors in the spontaneous combustion process, such as mining conditions and practices, and geologic factors. However, it is an important first step in determining the risk of a spontaneous combustion mine fire, and can have a significant impact in its prevention.

For More Information

For a single copy of the expert system program (on a 5-1/4-inch diskette for IBM PC or compatibles) or for answers to technical questions concerning this study, please contact:

Alex C. Smith
U.S. Bureau of Mines
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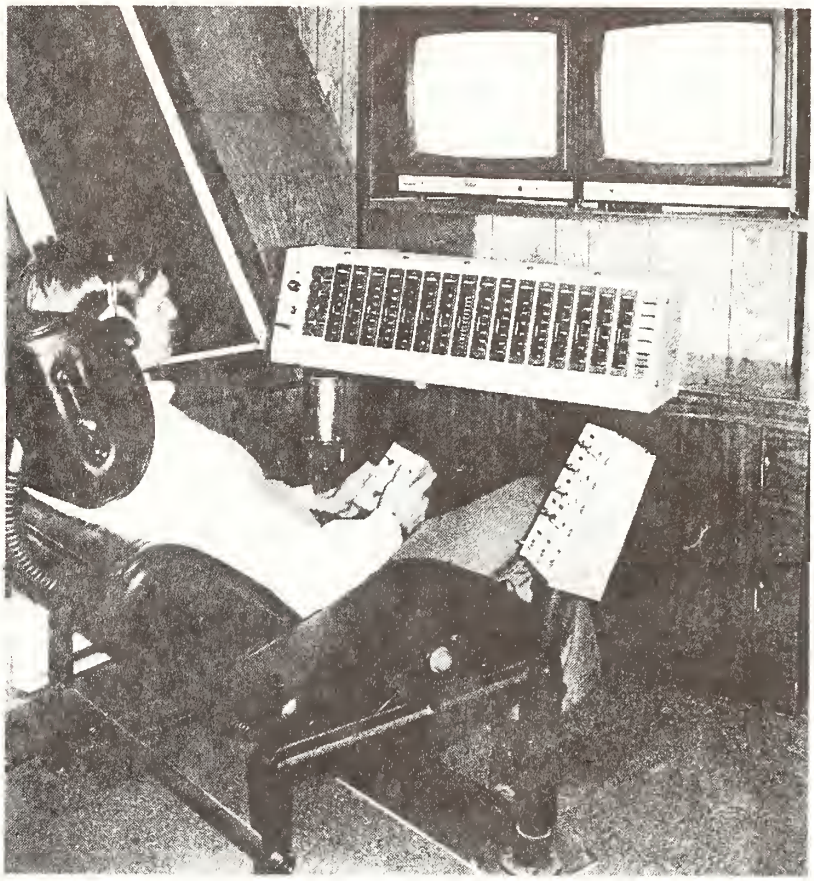
New Technology from the U.S. Bureau of Mines

U.S. Department of the Interior

Highwall Coal Mining is Controlled From Station on Bench

Three newly developed systems were combined to mine coal from a drift into a seam in a highwall while no miners were in the pit. The key to this demonstration was a Bureau of Mines developed system that monitors and controls mining from a considerable distance. That system was used, along with a manufacturer's thin-seam miner and the Bureau's Multiple Unit Continuous Haulage (MUCH) system, to demonstrate teleoperation mining. At this stage of development, teleoperation seems to provide a means of remotely mining open pit highwalls.



Teleoperator workstation allows operator to control mining of the highwall from a place outside of the pit.

Teleoperation mining tests are continuing at other highwall mines, and they could lead to a relatively safe means of winning the vast resources of coal that are presently unmineable from hazardous highwalls.

Teleoperation mining was initiated with the ultimate goal of controlling underground mining at a considerable distance from the face, possibly from the surface. Further tests in highwall mines, as well as other developments, are expected to continue progress towards the goal of avoiding health and safety hazards that are found near faces in underground mines. In particular this system could eliminate the hazards caused by the movement of large mining machines in those congested areas.

The overall system tested featured: the teleoperating system, a Jeffrey model 102HP thin seam continuous miner, the Bureau-developed MUCH conveying system, and some support equipment that was located on the highwall bench. Three workers controlled the operations within the highwall, but

none of them were permitted in the pit.

A single person, the teleoperator, controlled all the coal mining and haulage equipment penetrating the highwall. That miner was located at a human-engineered, workstation within a protective enclosure on the highwall bench. A computer-based electronics system controlled communications between the teleoperator and the mining equipment.

Two microprocessor systems were used—one in the work station and the other on the continuous miner. The teleoperator's commands, audio/video signals, and sensory data were transmitted between the work station and the mining equipment over small cables that ran alongside power and water lines.

Successful mining is critically dependant upon the teleoperator-machine interface. Therefore, major emphasis was placed on the design of optimum human engineering features for the workstation.

The teleoperator sat in a semi-reclined position on a special adjustable task chair. Convenient access was provided to: clustered controls, readout instrument panels, and video monitors. Information, from an array of sensors within the teleoperated highwall mining system, was presented in color-coded bars, displayed on a screen in an adjustable, swing-away console that was located in front of the operator. The main controls were grouped on a small hand-held module; secondary controls were located on an adjustable, floor-mounted panel next to the operator's task chair. Two 19-inch color video monitors were housed in a custom cabinet located at the optimum viewing distance from the operator's eyes. The video monitors provided views from closed-circuit video cameras mounted on the mining machinery. The operator also listened to sounds through a special system that focused on mining operations and minimized extraneous noise. A patent, entitled "Cutting Sound Enhanced System for Mining Machines," has been applied for.

Accomplishments included:

- Mining coal on the initial attempt, even though the teleoperator had no prior experience in controlling a mining system.

- Meeting or exceeding design goals for the new parts of the teleoperating subsystem. These subsystems included: closed-circuit videos, other machine-mounted sensors, the computers and software, the special sound subsystem, and the human-engineered workstation.

- Successfully using other Bureau-developed subsystems such as the prototype MUCH system and a unique ventilation subsystem. A patent, entitled "Suspension Mechanism for Flexible, Retractable Air Conduit", has been applied for.

- For brief periods the teleoperated highwall mining system demonstrated impressive production rates.

FOR ADDITIONAL INFORMATION: For further information about teleoperation mining, contact: Office of Technology Transfer, U.S. Bureau of Mines - MS 6201, 810 - 7th Street, NW, Washington, DC 20277-2666.

Sandia National Laboratory

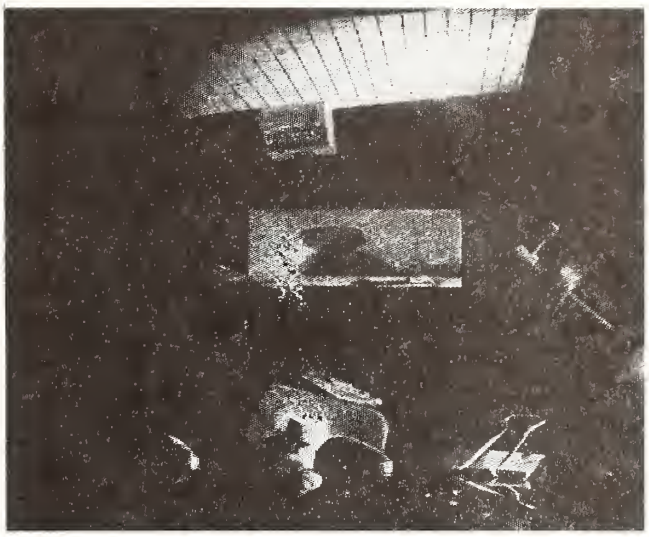
First Hologram Made of Hypervelocity Impact at 4.2 km/sec

Researchers at Sandia National Laboratories have obtained a hologram—a three-dimensional image in which the objects appear to float in space—of the shattered debris from a hypervelocity impact at 4.2 kilometers per second. This is 2.6 miles per second, or 9,400 miles per hour.

This is thought to be the highest velocity impact event ever successfully imaged by a hologram.

Conventional holography generally requires exposures of about one second or more. This usually restricts the method to stationary objects. Sandia's Pulsed Holography Development (PHD) project is attempting to use extremely short pulses—no more than 5 billionths of a second—from a very bright laser to obtain pulsed holograms of hypervelocity impacts.

Such holograms will be a valuable diagnostic tool for studying the damage caused by impacts at hypervelocities and the fragmentation and particulation from such impacts. This should help in the design of orbital debris shields and in better understanding the generation of orbital debris and the breakup of satellites.



Conventional, open-shutter camera photograph of 4.2 km/sec impact event shows experimental setup for holographic imaging of same event at same instant. Shattered debris is illuminated by same 5 nanosecond laser pulse used for creation of image on sheet of holographic film (along bottom).

High velocity is unique

"What's unique here," says Sandia project leader James A. Ang of the new Sandia achievement, "are holographic images of much higher velocity impact events." Previous work could holographically image impact events up to 1 kilometer per second—less than 25 percent of the Sandia capability.

"This capability allows researchers to go back after the fact and get a good idea of the shape, size, and distribution of fragments from an impact," says Ang. "Other techniques—photographs and flash x rays—don't have the resolution and depth of field to resolve very small fragments. Also, the other techniques are two-dimensional. This really is a three-dimensional image, and that allows much better comparison with new, three-dimensional computer codes."

The project is working to obtain holograms of still higher impact velocities and of larger fields of view. It is also seeking to develop a quantitative data-reduction system for analyzing the holographic images and comparing information from the images with the digital output from three-dimensional computer simulations of impact events.

The experiment was carried out using one of five high-velocity gas guns at Sandia's STAR (Shock Thermodynamics Applied Research) facility. The two-stage terminal ballistics facility gun fires a piston which compresses hydrogen gas that launches a projectile into a test chamber. (The gun and test chamber combined are about 45 feet long.)

In the experiment a 6.4-millimeter-diameter (1/4 inch) steel ball was fired through a 1.6 mm thick sheet of acrylic plastic at 4.2 kilometers per second. The steel ball shattered into several hundred fragments. A 5-nanosecond pulse of coherent light from a bright laser (750 millijoule pulse energy, 532 nanometer wavelength) was divided into two beams. One beam traversed the field of debris fragments before traveling to a sheet of holographic film placed at the front side of the test chamber. The second beam, a reference beam, traveled directly to the film. The film recorded interference patterns from the two beams.

The holographic image is reconstructed by illuminating the developed film from the side with another laser. An observer can then see a virtual image of the fragments seemingly floating in space behind the film. By moving his head laterally, he can see the three-dimensional image from various angles.

Validate 3-D computer codes

It is difficult to represent this three-dimensional holographic image two dimensionally.

A conventional photographic image made of the same event at the same time also shows the shattered debris as well as the test chamber setup. It was made using an open-shutter camera (with regular film) placed at an observing port at the top of the test chamber. The light source was the identical 5-nanosecond laser pulse used to make the hologram.

"While these hypervelocity impact event holograms are fascinating to view, their real utility will be for validating computer codes widely used for 3-D simulations of hydrodynamic events. A key project goal for 1992 is to develop techniques for extracting quantitative information from these holograms."

Ang is in Sandia's Experimental Impact Physics Division. Other members of the PHD project team are Dave Cox, Randy Hickman, and Scott Gosling, at the STAR facility, and Bruce Hansche and Bill Sweatt, photometrics support.

FOR ADDITIONAL INFORMATION: Technical Contact: James Ang (505) 844-0068, Department of Energy, Sandia National Laboratories, Albuquerque, NM 87185-5800.

NAVY
Domestic Technology Transfer Fact Sheet

'Touch' Added to New Keyboard

Figure 2. TCK keyboard

The Naval Surface Warfare Center Dahlgren Division, Dahlgren, Virginia, has been evaluating the Ternary Chord Keyboard (TCK), which features just eight keys but has four times the capability of its ancient counterpart.

Each of the keys have three positions: forward, neutral, and backwards. The neutral position is a nonfunctioning position, only the forward and backward key positions and combinations thereof produce usable functions. Therefore, mathematically you have combinations to the eighth power of 2 or 256 positions.

The typist will be "chording" instead of "pecking" to create the printed word. It is obviously less work and much faster to chord eight keys than to hunt-and-peck 64 keys, and it can be learned by a novice in about three hours. The TCK can do everything the old keyboard can, except it can do it better and without the muscle strain associated with the old keyboard.

For Additional Information:

Backup material on this effort is available from:

Navy Domestic Technology Fact Sheet Reader Reply Service
Code E211
Naval Surface Weapons Center
Dahlgren, VA 22448-5000
(703) 663-8921

Refer to 170103/TN

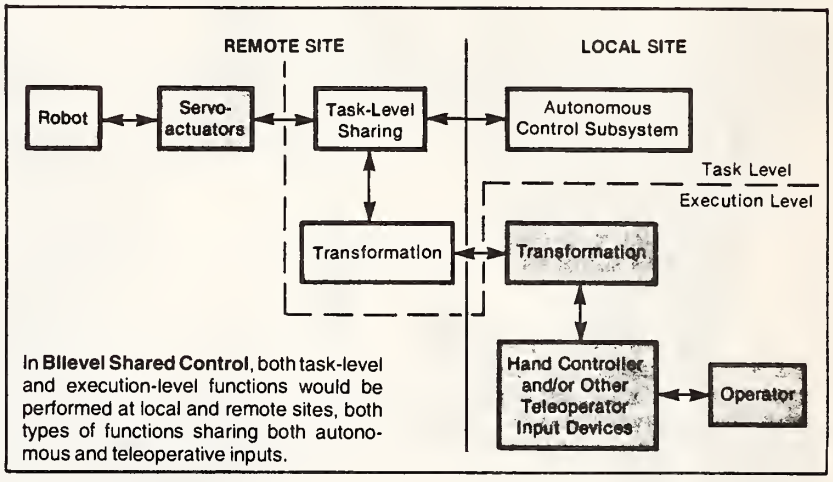
NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Bilevel Shared Control of a Remote Robotic Manipulator

Teleoperator and autonomous modes would be blended, each overcoming deficiencies of the other.

A proposed concept for the control of a remote robotic manipulator calls for a blend of autonomous and teleoperator (hand-control or other commands from the human operator) control modes. The concept is called "bilevel shared control" because it calls for a two-level hierarchical control system that would accept commands in both modes at both levels, sharing control between the two modes in such a way that each mode would overcome some of the deficiencies of the other. The concept is particularly applicable to a robotic system characterized by a long communication delay between the local (operator's control) site and the remote (robotic-manipulator) site or to a robotic system intended to function partly autonomously, with occasional intervention by the operator.



In Bilevel Shared Control, both task-level and execution-level functions would be performed at local and remote sites, both types of functions sharing both autonomous and teleoperative inputs.

Recent articles in *NASA Tech Briefs* described aspects of multilevel hierarchical control. To recapitulate: The control hierarchy ranges from larger digital processors and the associated software at the highest (task-planning) level down through smaller digital processors with lower-level software and possibly some digital/analog interface circuitry at intermediate (partly planning, partly reflex-action) levels, to more digital/analog interface circuitry, control actuators, and sensors at the lowest (execution) level. In bilevel shared control, such a hierarchy would be simplified to only the high (task) level and the low (execution) level.

In a bilevel shared-control system, functions at both levels would be performed at both the local and remote sites (see figure). At the local site, a planning algorithm would generate task-level autonomous commands, which would be transmitted to the remote site. At the same time, the operator would acquire (1) visual information about the remote manipulator and its surroundings through television displays and (2) tactile information about the contact and inertial forces on the manipulator via a force-reflecting hand controller. In response to this sensory information, the operator would generate teleoperative commands to correct the movements of the manipulator.

The autonomous commands to be generated by the planning algorithm would include the specification of (1) a coordinate system (called the "task" coordinate system) attached to the remote manipulator and (2) high-level task trajectories in this coordinate system. A hybrid position/force scheme would be used to represent low-level tasks in terms of simpler motion and force trajectories specified in the sets of orthogonal motion and force coordinates that would constitute the task coordinate system. To blend the autonomous and teleoperative control modes, it would be necessary to transform the teleoperative commands from the hand-controller (local) coordinate system to the task (remote) coordinate system. Part of this transformation would be performed locally and part remotely: the part of the transformation that involves the robot-joint angles would best be done remotely where communication delays were significant because the angle information would, thereby, be less outdated.

At the execution level, the commanded trajectories could come directly from the autonomous part, the teleoperator part, or a mixture of the two. For this purpose, it is necessary only that the servocontroller be capable of tracking the commanded motion and/or force trajectories in a stable fashion. To reduce the detrimental effects of communication delays, whenever such delays were significant, integration of teleoperator and autonomous commands would be allowed only along directions of motion, while forces would be controlled autonomously. The integration would be effected by determining when and how the two types of commands may be mixed, and performing the mixing process in software via a mixing matrix, the entries of which would reflect the relative weight given to each teleoperative and autonomous input.

This work was done by Samad A. Hayati and Subramanian T. Venkataraman of Caltech for **NASA's Jet Propulsion Laboratory.**

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL. Refer to NPO-17800/TN.

Jet Propulsion Lab.
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FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center, Houston, Texas

Electrochemical System Would Supply O_2, H_2O, N_2, and H_2

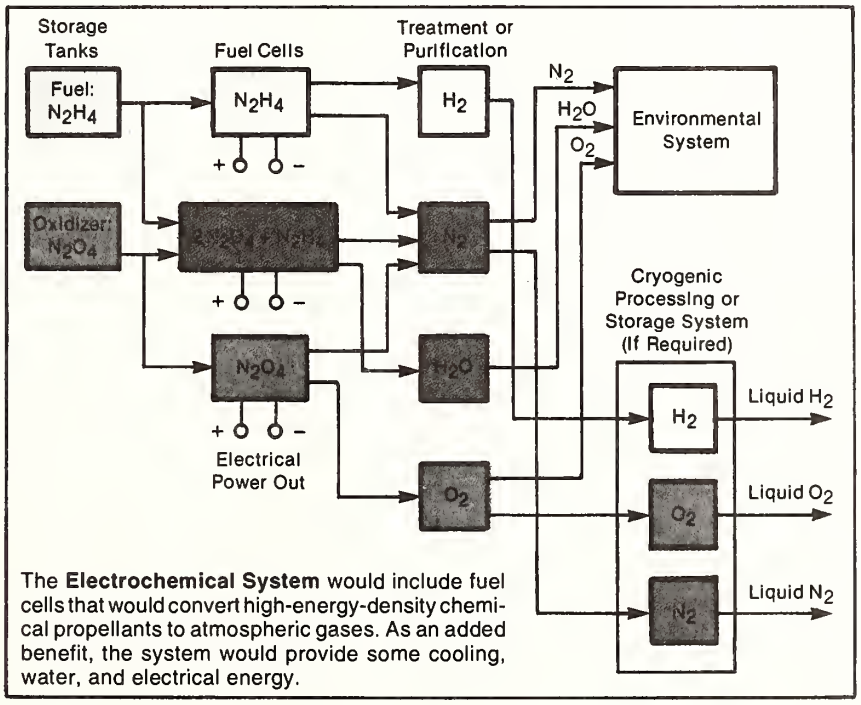
Atmospheric gases would be stored in propellant rather than compressed.

A proposed electrochemical system would generate O_2, H_2O, N_2, electrical energy, and (optionally) H_2 from hydrazine (N_2H_4), nitrogen peroxide (N_2O_4), and their derivatives, which are normally used as propellants in rocket engines. While intended primarily to supply atmospheric gases for the inhabited portion of a spacecraft, the concept of the system may be applicable to some terrestrial enclosed environments, laboratories, chemical processing plants, or portable medical facilities.

The electrochemical process (see figure) is based on the reactions $N_2O_4 \rightarrow N_2 + 2O_2$, $N_2O_4 + 2N_2H_4 \rightarrow 3N_2 + 4H_2O$, and (optionally) $N_2H_4 \rightarrow N_2 + 2H_2$. The reactions would take place in fuel cells and would consume heat in the comfortable range of room temperatures. Thus, the system could also be used to cool the enclosed environment. The electrical energy generated by the fuel cells could be supplied to other systems, and the byproduct water could be purified for consumption. The purified gases could be fed to the environmental system or stored in a conventional cryogenic system.

The system is expected to generate more oxygen or nitrogen per unit overall weight than can be stored conventionally as compressed gas or refrigerated liquid. According to a preliminary estimate, the weight of the electrochemical cells and associated equipment would be less than 100 lb (45.4 kg).

This work was done by Richard T. Walter of **Johnson Space Center** *and Paul D. Van Buskirk of Lockheed Engineering and Sciences Co., Inc.*
MSC-21404/TN



The **Electrochemical System** would include fuel cells that would convert high-energy-density chemical propellants to atmospheric gases. As an added benefit, the system would provide some cooling, water, and electrical energy.

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

PC-Based Program for Air-Stripper Design and Costing (ASDC)

Packed-tower, countercurrent air stripping is being employed with increasing frequency for removal of volatile organic compounds (VOCs) from contaminated water. Several studies have shown that air stripping, even with off-gas treatment, can be cost-effective for removal of VOCs from water.

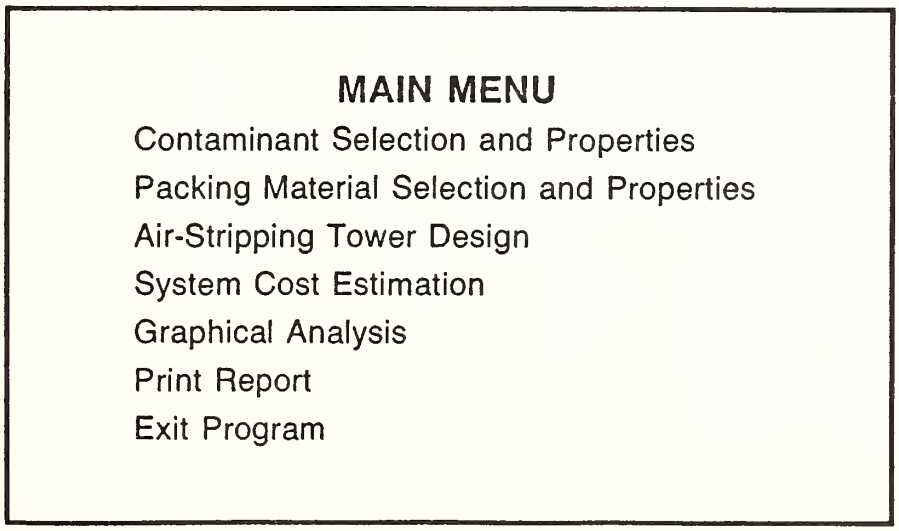
Design of an air-stripping unit is performed using a well-developed mathematical model of the process, based on principles of mass transfer. Because the number of variables involved exceeds the number of constraining equations, a variety of air stripper designs can be employed. Each unit can meet certain removal requirements, but can have drastic differences in operating and maintenance costs.

A user-friendly PC-based program to design air strippers has been created to ensure selection of the optimum unit.

The menu-driven program, written in C language, contains databases on costs and chemical characteristics. It also contains other pertinent information needed to design an optimum air stripper. The databases include 114 common contaminants and 57 variations of packing material. The databases can be expanded with a system-prompted internal program.

The cost model incorporated in ASDC enables comparison of approximate costs for different designs. Major capital and operation costs are evaluated for each design by summing individual component capital and operating costs. Features that enable modification of some cost factors (for example, packing material unit cost, electricity rate) and adjustment for inflation are included in the program. Up to 144 separate designs can be run simultaneously.

The various components of ASDC, as well as the entire program, have been tested to verify that the software correctly represents the design and cost models employed. Tests for some critical subroutines in the program such as the variation of Henry's Law constant with temperature are outlined in the report. In addition, ASDC



ASDC Main Menu

predictions of air-stripper performance and cost are compared to performance and cost data for some actual air-stripping units in the last section of the report.

The technical report, which also serves as a user guide to the program, is ESL TR 91-40, *Air Stripper Design and Costing: A Microcomputer-Based Program for Air Stripper Design and Costing*, due for publication in April 1992.

FOR ADDITIONAL INFORMATION: A copy of the software is available at nominal copying cost from: Dr. David Dzombak, Department of Civil Engineering, Carnegie Mellon University, Pittsburgh, PA 15213-3890. Government agencies can obtain copies at no charge from: Chemical/Physical Treatment Technology Area Manager, HQ AFCESA/RAVW, Tyndall AFB, FL 32403. (Include two double-density diskettes with your request.) TECHNICAL CONTACT: Capt. Ed Marchand, HQ AFCESA/RAVW, Tyndall AFB, FL 32403-6001; DSN 523-6023.

NASA Tech Brief
National Aeronautics and Space Administration

Designing Assemblies of Plates

VICONOPT facilitates design and analysis with respect to buckling and vibrations.

VICONOPT is a computer program that calculates vibrations and instabilities of assemblies of prismatic plates. The program provides capabilities for optimization and the imposition of constraints. It is designed for efficient, accurate analysis of buckling and vibration and for the optimum design of panels of composite materials.

VICONOPT can be used either as an analysis program or as an optimum-design program. The analysis features cover the calculation of eigenvalues — i.e., the critical load factors in buckling problems or the natural frequencies in undamped-vibration problems — with the option of finding the shapes of the corresponding vibrational modes and associated levels of perturbation stresses. The optimum-design features use the results of buckling analysis within a sizing strategy to converge on a safe design of low (nearly optimum) mass.

VICONOPT includes two major components: VIPASA — Vibration and Instability of Plate Assemblies Including Shear and Anisotropy; and VICON — VIPASA With Constraints. Optimization is accomplished by use of CONMIN — CONstrained function MINimization, (ARC-10836) in a manner similar to that used by PASCO — Panel Analysis and Sizing COde (LAR-13164). Improvements in the sizing strategy have greatly reduced the time required for optimization.

VIPASA implements the stiffness-matrix method based on the exact theory of flat plates. It also incorporates a theoretically derived algorithm that guarantees convergence on all required eigenvalues. This enables the user to employ multilevel substructuring very concisely and flexibly to reduce solution times, data-preparation times, and memory usage. VIPASA is based in part on the assumption of modes with sinusoidal longitudinal variation of half-wavelength λ, whereas VICON modes are sums of such modes. In VICONOPT, Lagrangian multipliers are introduced to constrain the response to be compatible with rigid or elastic supports, including transverse beams attached at arbitrary locations. If no constraints are present so that VIPASA may be used, the results are exact. While an infinite number of λ's are theoretically necessary to make VICONOPT exact, only a few are usually required to achieve engineering accuracy.

The VICONOPT sizing strategy involves three types of resizing steps: the initial stabilization step, the CONMIN optimization step, and the final stabilization step. The initial stabilization step brings unstable or overstable initial designs to a "just" stable configuration by altering design variable thicknesses to converge on a configuration such that the most critical eigenvalue for the set of buckling modes specified by the user becomes unity. The CONMIN optimization step entails linear programming techniques that alter design variables so that the mass of the assembly of plates is reduced without violating the buckling and configurational constraints. The final stabilization step returns the optimized configuration to a "just" stable condition. This step is necessary because the linearizing assumptions made during optimization are likely to require correction.

VICONOPT was written in FORTRAN 77 for implementation on DEC VAX-series computers. The main memory requirement is approximately 2 Mb. The program is available on a 9-track, 1,600-bit/in. (630-bit/cm) magnetic tape in VAX BACKUP format (standard medium) or a TK50 tape cartridge. The program should be readily adaptable to any workstation or to mainframe-class computers with a few modifications, which are outlined in the documentation. Graphical output can be obtained easily on most computers, inasmuch as the only graphical routines required are those to move, draw, and write text. VICONOPT was developed in 1990.

DEC VAX and VMS are trademarks of Digital Equipment Corp.

This program was written by F.W. Williams, D. Kennedy, R. Butler, and G. Aston of University of Wales College of Cardiff and M.S. Anderson of Old Dominion University for **Langley Research Center.** *LAR-14523/TN*

FOR ADDITIONAL INFORMATION

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U.S. Navy Fact Sheet

Naval Surface Warfare Center

Remotely Operated Vehicle

The Naval Surface Warfare Center, Carderock Division, has developed an Overside Noise Measurement System for Acoustic Diagnostic Investigations. The system consists of an acoustic sensor mounted on a computer-controlled, remotely operated vehicle (ROV), a tethered unmanned underwater robot. Any underwater structure or ship hull can be acoustically evaluated by positioning the ROV and hydrophone probe at various locations along the structure where it will measure the sound pressure levels. Different shipboard equipment can be operated to evaluate each system's contribution to the overall acoustic profile. Because the Overside System is capable of measuring the acoustic intensity field in close proximity, it is able to detect and accurately locate noise sources. Corrective action can then be taken to eliminate the noise source.

Typically, ROVs are controlled by an operator who uses hand-held joysticks to activate the ROV's thrusters to achieve the desired vehicle motion. However, the limited underwater visibility and lack of visual reference points for the operator make it necessary to use an underwater navigation system and computer-based controller to accurately position the ROV relative to the hull.

The Overside System can be used in a harbor or pier side environment because of the sound intensity method's ability to discriminate against background noise. The integration of the positioning system with the computer-based control system allows for positioning the ROV very accurately in zero visibility conditions. The Overside System is portable and can be deployed rapidly at any port without support from shipyards. As a result, acoustic diagnostic work can be performed with minimal impact on schedules.

For further information, contact Dr. Basil Nakonechny, (301) 227-1037.

Nondestructive Inspection of Large Structural Components

The size and density of large-scale structural components such as concrete containment walls make quality control testing extremely difficult. Even testing core samples can be damaging, expensive, and time consuming. An economical, portable system developed at the Pacific Northwest Laboratory supplies a radiation field that penetrates the structural component and a detection sensor with associated analysis and recording.

The technology offers significant breakthroughs in the quality control of large buildings and building components. Until recently, conventional inspection techniques have been hampered because of the physical limitations in assessing the interior regions of such structures. Inspection might be accomplished by taking core samples of components at different points. However, this would involve damaging or degrading the components themselves as part of the test procedure and is an expensive and time-consuming undertaking for structural components of significant size.

The method identifies voids, areas of reduced thickness or density, and honeycomb conditions without incurring possible damage. The process is rapid, efficient, and economical.

The inspection system consists of two mechanical modules for source and detection. Both modules are easily operated by means of a microprocessor control system. The source module moves, on wheels, to the area targeted for examination. The detection module, a scintillation detector, is aligned with the source module--but on the opposite side of the component being measured.

As the two modules track along the structure, the source provides a continuous beam of radiation that penetrates the structural component. Simultaneously, the detector measures the intensities of transmitted radiation.

This information is relayed to the control system and is tabulated in conjunction with information about the positions of the source and detector modules for a large number of sampling points. The results are recorded for analysis. The intensity levels at the various sampling points indicate the nature and degree of construction integrity at all points of measurement.

This technology is especially attractive for inspection teams who must gauge the integrity of building components, bridges, retaining walls, and other large, dense structures.

For additional information, contact Alex Fassbender, (509) 375-2225.

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

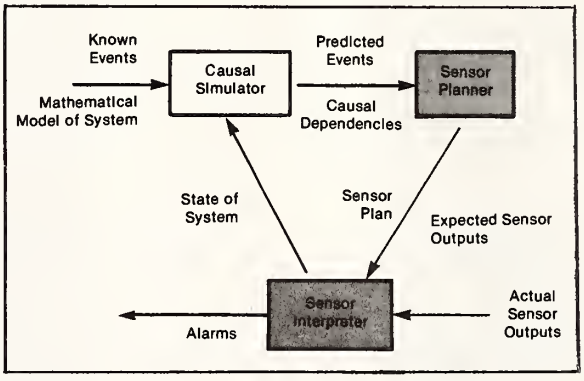
Predictive Monitoring With Many Sensors

A few sensors would be selected according to the state of the monitored system.

A proposed method of predictive monitoring that would prevent a large number of sensor data from overwhelming a human operator or an electronic monitor is a subject of continuing research. The essence of the method is to select only a few of the many sensors in the system for monitoring at a given time and to set the alarm levels of the selected sensor outputs to reflect the limits of expected normal operation at the given time. The method is intended for use in a highly instrumented system that includes many interacting components and subsystems; e.g., an advanced aircraft, an environmental chamber, or a chemical-processing plant.

Several considerations motivate the research on this method. Typically, the timely detection of anomalous behavior of a system and the ability of the operator or electronic monitor to react quickly are necessary for the continuous safe operation of the system. In the absence of a sensor-planning method, an operator may be overwhelmed with alarm data that result from interactions among sensors rather than directly resulting from anomalous behavior of the system. In addition, many of the raw sensor data presented to the operator may be irrelevant to an anomalous condition. The operator is thus presented with a great deal of unfocused sensor information, from which it may be impossible to form a global picture of events and conditions in the system.

The predictive-monitoring method would be implemented in a computing system running artificial-intelligence software, which has been tentatively named "PREMON." The predictive-monitoring system would include three modules: a causal simulator, a sensor planner, and a sensor interpreter (see figure). As used here, "event" denotes a discontinuous change in the value of a given quantity (sensor output) at a given time. The inputs to the causal simulator would include a causal mathematical model of the system to be monitored, a set of events that describe the initial state of the system, and perhaps some future scheduled events. The outputs of the causal simulator would include a set of predicted events and a graph of causal dependencies among those events.



The **Predictive-Monitoring System** would concentrate limited monitoring resources on those few of the many sensor outputs of a system that are most important at the moment.

The sensor planner would use the causal-dependency graph generated by the causal simulator to determine which few of all of the predicted events are important enough that they should be verified. In many cases, the most important events would be taken to be those that either cause or are caused by the greatest number of other events. This notion of causal importance would serve as the basis for the selection of those sensors, the outputs of which could be used to verify the expected behavior of the system.

The sensor interpreter would compare the actual outputs of the selected sensors with the values of those outputs predicted by the causal simulator. Alarms would be raised where the discrepancies between predicted and actual values were significant.

This work was done by Richard J. Doyle of Caltech for **NASA's Jet Propulsion Laboratory.** *NPO-18013/TN*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

Environmental Science & Technology

0651 Environmentally Safe Manufacturing Technology - An Overview

0652 Waste Soy Oil to be Recycled

0653 Studies Confirm Value of Landfill Capping in Arid Places

0654 Indoor Air Pollutants from Household Product Sources

Testing & Instrumentation

0655 OHMSETT Facility Reactivated

0656 Groundwater Flow Sensor Should Aid Environmental Cleanup

Technology Assessment
U.S. Air Force

Environmentally Safe Manufacturing Technology - An Overview

After years of concentration on treatment, disposal, and cleanup of intentional and uncontrolled releases of pollutants to the environment, the US Congress, in 1990, passed the Pollution Prevention Control Act to address the historic lack of attention to source reduction. The Act declares as "the national policy of the United States that pollution shall be prevented or reduced at the source whenever feasible..."

Just how does the Pollution Prevention Act relate to the Department of Defense and the Air Force? It means that consideration of preventing or reducing pollutants must begin when the manufacturing process is designed and, therefore, the champions of pollution prevention must be the organization responsible for development and demonstration of new materials and manufacturing processes.

Unlike the body of law and regulation which has traditionally been enforcement oriented, the Pollution Prevention Act does not envision a "sheriff at the door" incentive. The Act instead requires the Environmental Protection Agency to emphasize multi-media prevention of pollution, to ensure that industry obtains information and technical assistance to overcome institutional barriers to the adoption of source reduction practices, and to provide financial assistance to states supporting their programs. The USAF Manufacturing Technology Program can play a major role in this effort.

The urgency of this effort cannot be overstated! Several environmental laws already on the books are "technology forcing" because they outlaw use of certain materials (such as chlorofluorocarbons which deplete stratospheric ozone), ban disposal , or prescribe ever more restrictive control and treatment requirements. Failure on the part of industry or the DOD to develop, demonstrate, or introduce use of alternative materials and processes will impact program schedules, cost, and performance and continue the perpetual liability for cleanup of any future releases of hazardous materials or wastes.

In response to this environmental need the USAF Manufacturing Technology Program initiated the Source Reduction Strategy, one of the primary methods whereby source reduction technology advancements can be developed, demonstrated and disseminated to defense contractors and industrial installations. This program for pollution prevention has three important goals:

- First, there is the goal of structuring every program initiative in terms of achieving technical goals without sacrificing environmental values. Environmental acceptability needs to be cultivated in the same fashion as cost effectiveness and product safety. Any new or emerging technology development which commits to waste of scarce nonrenewable natural resources, necessitates use of toxic materials, or involves the generation of hazardous by-products must be the subject of a concerted effort to find environmentally safe alternatives.
- The second goal is finding alternatives to existing manufacturing technologies which entail use or generation of toxics or waste of valuable, critical, or strategic materials. This goal will be expressed in terms of a priority list of substances (materials and chemicals) targeted for source reduction.
- Third is the goal of investigating, developing, and demonstrating new environmentally safe manufacturing or repair technologies which my be acceptable alternatives to existing technologies which have environmental liabilities.

The Source Reduction Strategy involves six elements: The first element requires the development of a comprehensive plan to achieve Manufacturing Technology pollution prevention goals in concert with the Air Force Pollution Prevention Action Plan. The plan will address tasks, schedules, required resources, organizational responsibilities, and establish means of measuring and reporting progress toward goal attainment.

The second element involves the capability of Wright-Patterson Air Force Base to evaluate, demonstrate, and/or qualify environmentally safe materials and industrial processes.

Next, coordinating source reduction technology initiatives with environmental agencies, other DOD organizations, industry, and research institutions to promote the exchange of technical information, collaborate in technology development, and facilitate technology insertion encompass of the third element.

The fourth element includes participation in technical networks and exchanges with expert individuals and organizations (public and private) to share technical information relating to pollution prevention and to establish access to environmental technical information libraries, databases, and other repositories worldwide.

The fifth element provides technical assistance to client organizations in efforts to develop and introduce environmentally safe technologies.

The final element involves the development of methods to provide maximum industry access to source reduction technology achievements, as well as participation in training and information initiatives associated with pollution prevention.

The USAF Manufacturing Technology Directorate is currently involved with many environmentally beneficial projects and initiatives, which will be reported on in future editions.

FOR ADDITIONAL INFORMATION: To discuss this effort further, contact: Project Engineer: Russell Kennard, Air Force Manufacturing Technology Program, ATTN: AFWAL/WL/MTX, Wright Patterson AFB, OH 45433-6533; (513) 255-4623.

Research Technology
Agricultural Research Service
U.S. Department of Agriculture

Waste Soy Oil to be Recycled

A procedure used to decaffeinate coffee can be adapted to clean and recycle wastes from vegetable oil refining. The process could mean less use of landfills to dump the wastes. It can also mean fewer fire hazards from oil-soaked wastes which are prone to spontaneous combustion on hot summer days, U.S. Department of Agriculture scientists say.

An average soybean oil refinery generates about 5,000 pounds of spent bleaching clay every day. That clay absorbs substances from the raw oil that a refinery doesn't want in the end product. At the same time, the clay soaks in some of the oil.

While refineries can chemically treat the clay to remove the oils, they must adhere to special requirements to safely dispose of the chemicals.

Scientists with the National Center for Agricultural Utilization Research in Peoria, Illinois said handling of waste clay and chemicals could be replaced by using supercritical fluid extraction. This is a process in which gases such as carbon dioxide are heated and pressurized to act like liquids. This process has been used for years to decaffeinate coffee; it now can be used to clean the oil-absorbing clay.

"We've developed a method using supercritical carbon dioxide that extracts excess oil from the clay," said Jerry W. Kink, the chemist who heads the extraction project. "Using carbon dioxide, a nontoxic and nonflammable substance, as an extraction medium eliminates the chemical disposal problem as well as the fire hazard," King said.

Supercritical extraction would allow refineries to recover almost all of the oil absorbed by the clay, he said. That clay would have the potential for being used again for oil refining. In both laboratory and pilot plant tests, 100 percent of the oil was removed from the waste clay.

King said extracted oil would be suitable for industrial applications. But, he added, the oil would need to be further refined if intended for human consumption.

Preliminary cost estimates indicate that using the process to extract oil would compare favorably with current methods, he said.

Supercritical fluids are gases such as carbon dioxide and nitrous oxide that are heated and compressed to densities resembling but never actually becoming liquids. For the waste clay, carbon dioxide was heated to 177.6 degrees F and subjected to 12,000 pounds of pressure per square inch.

For more details, contact Jerry King, (309) 685-4011.

Department of Energy

Technology Application

National Renewable Energy Laboratory

Studies Confirm Value of Landfill Capping in Arid Places

Recent research has dispelled concerns that conventional capping methods might not be effective in preventing the leaching of hazardous waste in landfills located in arid locations.

The studies, conducted at Sandia National Laboratories, found that even in desertlike conditions, impermeable caps prevent rainwater from seeping into the ground, which could wash landfill contaminants down to the water table. Researchers had initially been concerned that dry soils under the cap might act as a sponge, drawing water under the cap into the landfill from adjacent, wetter soils.

In wetter climates, the differences in moisture content between soils beneath landfill caps and adjacent soils would be less significant, making a "wicking" action less probable. Impermeable caps of gravel, clay, or concrete are widely used to minimize leaching from surface landfills. However, their performance and effectiveness in arid environments has not been adequately studied.

"We were concerned that contaminants could possibly travel a lot farther laterally in dry soil here in the Southwest than they do in the eastern United States," says Carol Stein of the Geochemistry Division. "Our preliminary results indicate that is not the case."

The studies support Sandia's site characterization studies for a chemical waste landfill cleanup project. *Technical Contacts: Carol Stein (505) 844-5576, David McTigue (505) 844-0450, and Steve Rottler (505) 844-3882.*

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Refer to Volume XIV, Number 1/TN

United States
Environmental Protection
Agency

Environmental Monitoring
Systems Laboratory
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Research and Development

EPA

Project Summary

Indoor Air Pollutants from Household Product Sources

Introduction

Since most people spend a large amount of time indoors at either home or at work, in often insufficiently ventilated buildings, there is an increasing concern about the presence of toxic vapors in indoor air. To address this issue, the Office of Pesticides and Toxic Substances (OPTS) and the Office of Air and Radiation (OAR) of the U.S. Environmental Protection Agency (USEPA) have been working to define pollutants and their levels and sources in indoor air, particularly in residential settings. In addition, the Office of Solid Waste and Emergency Response (OSWER), under the authority of the Superfund Amendments and Reauthorization Act (SARA), is concerned with minimizing disposal of household products containing toxic substances.

In order to identify household products that may be sources of indoor air pollution and contribute to disposal problems, this study reviewed an analytical data base of 1,159 household products compiled by Midwest Research Institute (MRI) for a previous study to determine the presence of common solvents[a]. The objective of the original work was to quantify six chlorinated target analytes (methylene chloride, tetrachloroethylene, carbon tetrachloride, trichloroethylene, 1,1,1 trichloroethane, and 1,1,2-trichlorotrifluorethane) by purge and trap gas chromatography/mass spectrometry (GC/MS). Full mass spectra were collected at that time and archived for later research. In the present study, computerized reduction of the archival GC/MS data was the method chosen to best estimate the concentration of 25 additional target analytes (See Table 1) in the samples. Supplementing the earlier work, this study provides data on the occurrence and estimated concentrations of those 25 additional chemicals in the household products.

Procedure

In the original study, 1,159 household products purchased from stores in six cities (Washington, DC; Denver, CO; Houston, TX; San Francisco, CA; Chicago, IL; and Miami, FL) were grouped into 65 product categories with each product given a sample code describing the sample, city of purchase, product category, product form, and sequential city/product number. The samples were analyzed by GC/MS at three laboratories: MRI, Envirodyne Engineers (St. Louis, MO), and Versar (Springfield, VA). The selection of the 25 target analytes in this study was based on the Total Exposure Assessment Methodology (TEAM) studies, analytes recommended by OPTS, and those cited in other USEPA programs. Of the 1,159 products, 922 were analyzed at MRI, 92 at Envirodyne, and 145 at Versar. Only 1,043 of the original total were available to be analyzed for this study.

Table 1. Indoor Air Pollutant Chemicals Used in the Household Product Survey

Analyte	Formula	CAS registry number
Acetone	C_3H_6O	67-64-1
Benzene	C_6H_6	71-43-2
2-Butanone	C_4H_8O	78-93-3
Chlorobenzene	C_6H_5Cl	108-90-7
Chloroform	$CHCl_3$	67-66-3
Cyclohexane	C_6H_{12}	110-82-7
1,2-Dichloroethane	$C_2H_4Cl_2$	107-06-2
1,4-Dioxane	$C_4H_8O_2$	123-91-1
Ethylbenzene	C_8H_{10}	100-41-4
n-Hexane	C_6H_{14}	110-54-3
Limonene	$C_{10}H_{16}O$	5989-27-5
Methylcyclohexane	C_7H_{14}	108-87-2
Methylcyclopentane	C_6H_{12}	96-37-7
Methyl isobutyl ketone	$C_6H_{12}O$	108-10-1
n-Nonane	C_9H_{20}	111-84-2
n-Octane	C_8H_{18}	111-65-9
a-Pinene	$C_{10}H_{16}$	7785-70-8
Propylene oxide	C_3H_6O	75-56-9
Styrene	C_8H_8	100-42-5
1,1,2,2-Tetrachloroethane	$C_2H_2Cl_4$	79-34-5
Tetrahydrofuran	C_4H_8O	109-99-9
Toluene	C_7H_8	108-88-3
m-Xylene	C_8H_{10}	108-38-3
o-Xylene[1]	C_8H_{10}	95-47-6
p-Xylene[1]	C_8H_{10}	106-42-3

[1] o- and *p*-Xylene coelute under the analytical conditions originally used and are treated as one analyte.

Apparatus

The purge and trap methodology used in the original study complies with EPA Method 624, "Purgeables." Although no actual samples were analyzed by GC/MS in this study, the same methodology was used for the analysis of calibration standards for the 25 additional target analytes. MRI's MAT CH4-B, one of the GC/MS systems used in the original study, was optimized to replicate the chromatographic

[a] Household Solvent Products: A "Shelf" Survey with Laboratory Analysis. Washington, DC: U.S. Environmental Protection Agency. EPA-OTS 560/5-87/006, 1987.

[b] Guidelines establishing test procedures for the analysis of pollutants: Method 624-Purgeables (40 CFR 136, Appendix A, pp. 432-446), 1988.

behavior observed for the original analyses, and was used to produce calibration curves for the 25 additional analytes. Reference standards of target analytes were obtained from Aldrich Chemical Co. Calibration standard solutions were prepared by accurate dilutions of the reference standards with high purity methanol.

GC/MS Data Processing

A Finnigan/INCOS data system was used for data acquisition and handling for both the analysis of the standards for the 25 new target analytes as well as reprocessing of the original GC/MS data files. Analysts used Finnigan's Target Compound Analysis (TCA) software to identify the target analytes based upon relative retention times and to compare the observed mass spectrum with an authentic spectrum obtained by the analysis of a standard solution. Each identification made by the TCA software was verified manually and edited, if necessary, to produce a completed quantitation report for each household product. Completed quantitation reports were transferred as ASCII text to a Macintosh II computer and archived on floppy disks. The ASCII quantitation reports were imported into a 4th Dimension custom designed data base, where they were reviewed, listed, modified, searched, and sorted using the software. After the concentrations of each of the 25 analytes were computed, that information was merged with the original data base containing the analytical information for the original six analytes.

Results and Discussion

Calibration System

The precision of the response factors for both the low and high level calibration curves for the 25 target analytes was less than 35%, which meets the EPA Method 624 calibration criterion. As the calibration was used to *estimate* the analyte concentrations obtained from several different instruments and laboratories, this limit was deemed acceptable. It was assumed that the relative responses of the target analytes obtained during the calibration were representative of the responses obtained during the original analyses.

Accuracy

For GC/MS analyses, accuracy is normally determined by the analysis of performance audit or calibration check samples which have been fortified with the known levels of the target analyte.

Occurrence of Target Analytes

The chemicals found most frequently in the household products were acetone (315 products), 2-butanone (200 products), methylcyclohexane (150 products), toluene (488 products), ethylbenzene (157 products), *m*-xylene (101 products), and *o,p*-xylene (93 products). A total of 63.6% of the household products analyzed contained one or more of the analytes at concentrations of at least 0.1% by weight. Five analytes: 1,1,2,2-tetrachloroethane, chlorobenzene, styrene, nonane, and *d*-limonene, were not found in any of the products at or greater than 0.1% by weight.

Conclusions and Recommendations

An archived collection of GC/MS data was reanalyzed for the presence of 25 common volatile chemicals in over 1,000 household products. The reanalysis provided the concentration and frequency of occurrence for each chemical in each of 65 product categories. The newly generated information was integrated into a computerized data base and configured for ready access by researchers.

The major accomplishment of this work is the compilation of analytical information for 25 common chemicals found in over 1,000 household products and integration of that information with the analytical information for the original six analytes. The data base described in this report is available from USEPA on diskette in a spreadsheet format.

The data base will be useful in future research efforts to assess exposure to these chemicals in the home environment. It should allow exposure assessment researchers to: conduct studies on the determination of household sources of specific chemicals; assess the potential of specific products to generate harmful vapors; and, character of the major chemical components of the household product. Further, based on the success of this study, it is feasible that the archived GC/MS data can be revisited to characterize the remainder of the volatile chemicals present in the household products.

The information in this document has been funded wholly or in part by the United States Environmental Protection Agency under Contract No. 68-DO-0137 to Midwest Research Institute. It has been subjected to the Agency's peer and administative review, and it has been approved for publication.

Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

T.M. Sack and D.H. Steele are with Midwest Research Institute, Kansas City, MO 64110
Joseph Behar *is the EPA Project Officer (see below).*
The complete report, entitled "Indoor Air Pollutants From Household Product Sources," (Order No. PB92-136837/AS; Cost: $26.00, subject to change) will be available only from:
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Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
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Las Vegas, NV 89193-3478

NAVY
Domestic Technology Transfer Fact Sheet

OHMSETT Facility Reactivated

The Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT) facility is a unique installation constructed by the Environmental Protection Agency (EPA) to test offshore oil spill response equipment and procedures. The Naval Surface Warfare Center Carderock Division, Carderock, Maryland, is a significant participant in the renovation, reactivation, and initial checkout of the facility. OHMSETT, when in operation, will be an environmentally safe facility to conduct testing and development of devices and techniques to control oil spills.

The Carderock Division is providing technical and administrative guidance for design, purchase, installation, and checkout of equipment required for the reactivation of the OHMSETT facility and subsequent tests.

The facility will be used to evaluate innovative detection strategies, including the use of remote sensing devices such as laser thickness sensors and laser fluorosensors for detecting oil concentration that have submerged.

For Additional Information:

Backup material on this effort is available from:

Navy Domestic Technology Fact Sheet Reader Reply Service
Code E211
Naval Surface Weapons Center
Dahlgren, VA 22448-5000
(703) 663-8921

Refer to 170302/TN

Department of Energy

Technology Application

Sandia National Laboratory

Groundwater Flow Sensor Should Aid Environmental Cleanup

A low-cost sensor that measures the speed and direction of groundwater is being developed at Sandia National Laboratories.

Called the In-Situ Permeable Flow Sensor, the technology is expected to be useful for toxic waste management and cleanup where groundwater has become contaminated. The sensor can be used to determine groundwater flow patterns, providing valuable information on the size of the contaminated area and how it might be spreading.

The Sandia device is considered to be more accurate than other flow sensors because it is permanently embedded in the ground rather than contained in an open borehole.

The sensor consists of a rod, measuring 30 inches long and two inches in diameter, with a cylindrical electric heater. An array of 30 thermistors (thermal resistors) on its surface measures temperature change as a function of electrical resistance.

The instrument is buried in a location after being lowered inside a hollow stem auger drill. In unconsolidated, or loose, soils, the soil fills in around the sensor when the drill stem is retracted, leaving the surrounding material in direct contact with the sensor.

Other sensors usually remain within their original boreholes, which can alter natural fluid flows and cause inaccurate readings of flow direction and velocity.

Powered by an above-ground power source, the Sandia sensor heats the surrounding soil and groundwater as it flows past the instrument. The thermistors measure the water's temperature, and the information is transmitted to a data acquisition system on the surface. The direction from which the water is coming is determined by detecting water temperatures—relatively cool water exists upstream, and warmer temperatures are registered downstream as the water is heated by the device. The pattern of temperatures recorded on the probe's surface indicates the direction of the fluid flow. The magnitude of the temperature variations is used to determine the magnitude of the flow velocity.

In cleaning up sites where hazardous chemicals have seeped into the ground, it must be determined whether they have reached the water table, how widespread the contamination is, and whether fluid flows are causing it to spread. Fluid flows within a contaminated site may be complex and diverse, factors that some flow sensors fail to detect.

The flow velocity derived from the permeable flow sensor is characteristic of a small area, an important factor in remediation, says researcher Sandy Ballard. Numerous sensors can be buried within the boundaries of a contaminated site to produce a highly accurate picture of complex groundwater flow systems.

The sensors are left in the ground, requiring their cost to be kept at a minimum. The production cost of each device is estimated to be less than $1,000. Installation costs, including drilling the hole, would probably cost another $500.

DOE holds the patent (#4547080) to the instrument. Science & Technology Corporation, an Albuquerque company, holds a nonexclusive license from DOE to commercialize the sensor.

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Manufacturing, Machinery & Tools

0657 Annunciator Enhancement

0658 Holographic Wafer Inspection

0659 Isothermal Forging Work Cell

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0661 New Method Uniformly Etches Tiny Micromechanical Devices

0662 Casting Modeling Advancement

0663 Electronic Improvements Mean Important Technology Transfer Opportunity

0664 Quantitative Process Automation Language

0665 Machine Tooling Makes 'Quantum Leap'

0666 Forming Solutions for Oxygen Breathing Apparatus

0667 Plasma Spray Initiative

0668 One-Dimensional Casting Model Addresses Mold Design Details

0669 Direct Adaptive Control of an Industrial Robot—Desirable features include fast sampling and accurate tracking of the commanded trajectory.

0670 Fastener for Hot, Oxidizing Environments—It can be assembled and disassembled quickly from the outside. (Licensing Opportunity)

0671 Latches for Equipment Drawers—A mechanism makes rack hardware interchangeable, regardless of drawer height. (Licensing Opportunity)

0672 Leak Stopper to Metal-to-Metal Tube Fittings—A plastic-coated steel device is both conformat and strong.

0673 Recursive Algorithms for Dynamics of Geared Robots—Inertias of motors and gears are taken into account.

Other Items of Interest

0644 Bilevel Shared Control of a Remote Robotic Manipulator—Teleoperator and autonomous modes would be blended, each overcoming deficiencies of the other. (Licensing Opportunity)

0651 Environmentally Safe Manufacturing Technology - An Overview

0677 Atlas of Formability for Understanding Material Characteristics

FOCUS: ELECTRONICS

TECHNOLOGY TRANSFER BULLETIN

AIR FORCE INDUSTRIAL BASE

Reference Number: MT92007E-FEB

Annunciator Enhancement

Aerospace Avionics, Inc.

Prime Contractor: General Dynamics, Fort Worth, TX

This subcontractor Industrial Modernization Incentives Program (IMIP) project was implemented at Bohemia, NY.

PROJECT PURPOSE

The Phase I analysis recognized that the (then) current method of producing annunciator panel legends was labor and scrap intensive. This project was established to introduce new equipment and procedures into the silk screening, lamination, and cutting operations to more efficiently produce high quality optical readout panels from polyester blanks.

APPROACH

The introduction of a semi-automated printer reduced the variability inherent in the manual silk screening process used to produce legends on polyester blanks. A console mounted thick film printer was fitted with an automatic carriage, an automatic head-lift, an air knife, and a double palm start to enhance efficiency and operator safety. Individual legends are cut from blanks using a 3-axis computer-numerical-control (CNC) milling machine featuring quick change tooling and cassette-tape storage of all programs. Capital equipment consisted of a Dyna-myte 2400 Milling Machine and a C.W. Price Model 8010 Thick Film Printer.

PROJECT BENEFITS

These fabrication process enhancements increased yield by 53%, decreased fabrication time by 26% and generated an internal rate of return greater than 40%. These results were realized by the innovative application of off-the-shelf equipment. The project benefits are based on actual "AS-IS" and "TO-BE" subcontractor data.

APPLICATIONS

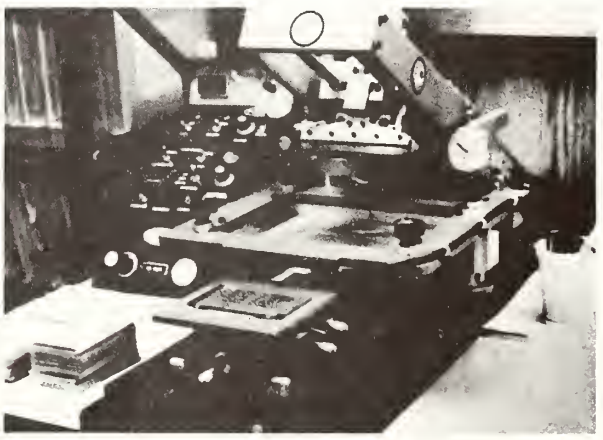
The development effort for this project was funded by the subcontractor (Aerospace Avionics). The technologies implemented are "off-the-shelf" with relatively short lead time for development, procurement and implementation. This project is a good example of a DOD subcontractor utilizing an IMIP initiative to identify and quickly implement "off-the-shelf" technologies to improve yield, reduce cost and decrease manufacturing lead time.

PROJECT STATUS

This project has been implemented. The semi-automated silk-screen printer and the 3-axis CNC milling machine are both being used.

TECHNICAL DOCUMENTATION

GD/Fort Worth IMIP abstract No. 27071A; The Project Final Technical Report has been submitted to DTIC.



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FOCUS: ELECTRONICS

TECHNOLOGY TRANSFER BULLETIN

AIR FORCE INDUSTRIAL BASE

Reference Number: MT92006E-FEB

Holographic Wafer Inspection

National Semiconductor Corporation

This project was conducted under the MANTECH program; a part of the Air Force Industrial Base Program which provides new manufacturing techniques to solve production and design-to-production problems. The Air Force MANTECH Program contracted with National Semiconductor to evaluate technology developed by Insystems.

PROJECT PURPOSE

Optical microscopes have been the primary tool for defect detection and evaluation of silicon wafers during integrated circuit fabrication. As minimum feature sizes shrink, magnifications are increased, thus decreasing field of view and depth of focus and dramatically decreasing inspection area for a given inspection time. Holographic inspection seemed a promising alternative to current inspection methods. It offered an efficient technique for highlighting process signatures over an entire wafer. The purpose of this program was to assess and optimize holographic techniques for application to silicon wafer inspection.

APPROACH

This project consisted of two phases:

phase I - Assessing the application of holographic technology for wafer inspection with respect to pattern complexity and defect resolution, and establishing a baseline for yield correlation.

phase II - Optimizing wafer inspection relative to in-process inspection and yield correlation.

The model 8600 holographic wafer inspection system, built by Insystems of San Jose, CA, was used for the program.

PROJECT BENEFITS

Unlike other inspection techniques, holographic inspection allows the generation of wafer maps which reveal whole-wafer process signatures, giving the process engineer a snapshot of the process. Problems in the process or in wafer handling can be easily identified in real-time for correction. Benefits include:

- Reduced wafer inspection time per area inspected.
- Real-time, in-line process control.
- Feedback to the process for continuous process improvement.
- Extensive technology transfer to the US semiconductor industry.
- Lower costs and shorter lead times for military devices.

APPLICATIONS

This technology applies to silicon wafer inspection.

PROJECT STATUS

This MANTECH project was completed in August, 1991.

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TECHNICAL DOCUMENTATION

The following interim reports are available through the Defense Technical Information Center: WRDC-TR-89-8036; WL-TR-91-8044; WL-TR-91-8051. Final report estimated availability: March, 1992.

GOVERNMENT SPONSOR

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FOCUS:
METALS

TECHNOLOGY TRANSFER BULLETIN

AIR FORCE INDUSTRIAL BASE

Reference Number: MT92002M-FEB

Isothermal Forging Work Cell

United Technologies - Pratt & Whitney

This Industrial Modernization Incentives Program (IMIP) project was implemented in Columbus, Georgia.

PROJECT PURPOSE

The Isothermal Forging Work Cell was developed to provide in-house capability to cost-effectively produce disks to near-net shape. This was accomplished through the integration of automation and computer-control into two isothermal forging units.

APPROACH

The Isothermal Forging Work Cell integrates modern material handling systems and computer controls with the isothermal forging process. The Cell further optimizes the disk forging process by improving process control, productivity and throughput. Robotic systems interface with automated conveyors to load and unload the forging presses. Individual machine controllers are driven by a cell microcomputer and are linked to the supervisory computer to schedule and control parts within the Cell. The implementation of state-of-the-art technologies such as automation and computer control helped to advance the isothermal forging process.

PROJECT BENEFITS

This IMIP project reduced scrap, rework and repair, enhanced productivity, improved production surge capability and incorporated computer control of all process variables. Significant material savings were achieved as a result of forging to near net shape, which also results in a savings of precious raw material. Since the process has been implemented, 50,000 disk forgings have been produced with less than 1/10th of 1% being scrapped or reworked.

APPLICATIONS

The technology is applicable to all isothermal forging houses.

LESSONS LEARNED

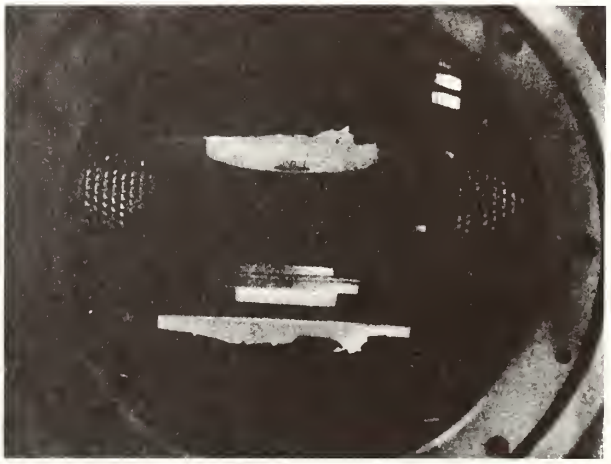
Substantial material savings are obtained when parts can be produced to near-net shape. As a result, two other Pratt & Whitney IMIP projects have been funded, which offer new manufacturing approaches to derive similar benefits: The Near-Net Shape Roll Forming Project and the Isothermal Forge Ring System.

PROJECT STATUS

The Isothermal Forging Work Cell was implemented in June, 1987.

TECHNICAL DOCUMENTATION

The final report is available from the Defense Technical Information Center (DTIC); report number AD-B 103880.



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FOCUS:
COMPUTER
INTEGRATION

TECHNOLOGY TRANSFER BULLETIN

AIR FORCE INDUSTRIAL BASE

Reference Number: MT92003CI-FEB

Manufacturing Support Graphics (MSG)

Rockwell International

This Industrial Modernization Incentives Program (IMIP) project was implemented at Cedar Rapids, Iowa.

PROJECT PURPOSE

Work instructions are typically hand generated, process related documents required for the assembly and inspection of electronic products. Manufacturing Support Graphics (MSG) is a system designed and developed to provide manufacturing with the ability to automatically create, revise, store, and maintain these work instructions.

APPROACH

The project was focused on the creation, edit and control processes due to the significant potential for cost reduction. The electronic distribution and viewing capability was scheduled for Phase III development and implementation. MSG utilizes a combination of the CAD system and the Comprehensive Manufacturing File (CMF) developed in related IMIP projects. The CAD system provides the graphics for the visual representation of the assembly. The CMF contains all of the component parameters and board location. The graphics and the parts list are merged to provide all relevant data for board assembly at each operation. Additional test files containing assembly notes or special instructions can be imported for inclusion by operation. The change control system tracks and edits each revision, storing the revisions for complete traceability.

PROJECT BENEFITS

MSG eliminates the manual effort required to create and maintain work instructions for the factory, without taking away the author's ability to customize the documents. It also provides the ability to track all changes to the work instruction and keeps a complete history throughout the product's life cycle. The result of using the CAD system is the implementation of an automated data link between the engineering CAD system and manufacturing, reducing the time required to get graphical data from engineering to manufacturing. The result of this automation has been a 58 percent labor reduction in the creation and revision process.

APPLICATIONS

The MSG system was designed for the electronic assembly of printed wiring boards. This is a two dimensional representation that can be applied to many other environments. Expansion into three dimensional representation is currently underway (see project status). The system can also be expanded to other documentation systems which include: component specifications, MIL Specifications, configuration and inspection test reports.

Continued on reverse side

PROJECT STATUS

The project was completed in February 1990 and has been implemented in both the Cedar Rapids and Coralville facilities. A similar IMIP project for the distribution and viewing of work instructions was completed by a sister division (Collins Defense Communication) in 1990. With the merging of these two divisions in November 1991, a new IMIP was proposed to interface the two IMIP projects to form a complete system for creation, edit, control, distribution, and viewing. This project is scheduled to begin in 1992.

TECHNICAL DOCUMENTATION

For more information concerning the Final Report, contact the Company point-of-contact.

GOVERNMENT SPONSOR

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Department of Energy

Technology Application

Sandia National Laboratory

New Method Uniformly Etches Tiny Micromechanical Devices

Researchers at Sandia National Laboratories have developed an improved process for uniformly etching silicon to create miniature parts used in micromechanical devices.

The process has attracted the attention of industry researchers, who are working with Sandia to investigate its manufacturing potential.

Single crystal silicon has long been used to produce integrated circuits, and its exceptional strength also makes it an ideal material for fabricating miniature sensors, motors, accelerometers, and other microdynamic devices. The sculpting of these tiny operating structures - measured in microns and often having complex three-dimensional geometries - is a relatively new engineering field known as micromachining.

Silicon removal techniques for crafting silicon wafers involve photolithography and chemical etching. With these techniques, the area to be removed is defined by a patterned mask and the material to be removed is dissolved in hydroxide baths at elevated temperatures.

For three-dimensional structures, these techniques are less desirable. Because the etch rate is dependent upon the temperature and bath composition, it is difficult to control precisely the amount of silicon to be removed. Chemical etching also tends to give the etched area a matte finish rather than the preferred mirror finish.

The Sandia process uses electrolysis of silicon in hydrofluoric acid to make porous a very thin layer of silicon on the top of a silicon wafer. Since the etching rate is directly proportional to the current passed in the electrochemical cell, the depth of the porous silicon can be easily regulated by controlling the charge passed through the electrochemical cell. The wafer is then removed from the cell, and the porous silicon is etched by immersing it in a hydroxide solution at room temperature. Because the pore depths are so uniform, the resultant etch finish is mirror rather than matte.

Terry Guilinger, a member of the research team that developed the process, says the "complete compatibility" of the method with standard wafer fabrication procedures makes it an attractive micromachining method.

"But perhaps the greatest attraction of this method is the assurance of a uniform product when fabricating multiple structures," he explains. "This intermediate, porous phase allows the volume to be etched away precisely and in a repeatable manner. We have demonstrated that we can duplicate the process repeatedly with no more than a 0.3 percent variance in results."

A patent on this process (No. 4,995,954) has been issued to the Department of Energy. Sandia is a multiprogram research and development facility operated for the DOE by AT&T.

A patent application also has been filed by the DOE for a humidity sensor fabricated by the new process. The sensor would be used to measure humidity inside microelectronic packages and other environments.

Under the DOE's Advanced Manufacturing Initiative program, researchers in Sandia's Center for Materials and Process Sciences and Silicon Technology Department are working with researchers from private companies and the University of New Mexico to refine the sensor as well as to investigate other uses of the anodic etching micromachining process.

FOR ADDITIONAL INFORMATION: Technical Contact: Terry Guilinger (505) 845-9043, Department of Energy, Sandia National Laboratories, Albuquerque, NM 87185-5800.

Technology Assessment
U.S. Air Force

Casting Modeling Advancement

The Manufacturing Technology Special Study on Ductile Iron Casting examined and evaluated different types of hardware and software used in modeling the iron casting process. The study team of Lufkin Industries, Inc., and Metalworking Technology, Inc. says success in producing a viable modeling system for the casting industry will significantly reduce design and production costs. The study evaluated such methods as green sand, no-bake sand and lost foam.

The feasibility of automating a casting modeling system is highly possible. A partially automated design system will apply consistent design practices identifying problem part and part detail geometry. A successful design system will achieve greatly improved part quality with reduced production costs. Other benefits include the capability to incorporate and integrate reproducible cost estimates and production scheduling data within the system. Process analysis can help verify a design in the preproduction phase.

During Phase I of this two phase effort, the team evaluated several expert system shells (artificial intelligence shells). They concluded that the modeling applications can be naturally served in an object-oriented system such as KES (Knowledge Engineering System). The structure of KES lends itself well to developing modules within the system that resist alteration by novice users. A major concern of the study was the tremendous amount of variables involved in the casting design process. To make the system feasible, limitations must initially be imposed, keeping implementation cost down. Real world limitations addressed included knowledge, resource, and budget constraints. Other constraints involving engineering and practical judgment are also possible as the casting modeling systems are refined under subsequent efforts.

Computer-Aided-Design (CAD) technology and geometry have limited application according to the Phase I results. CAD systems lend themselves well to a family-of-parts system, but only within the constraints of an object-based system. Even so, some of the benefits in using this approach are: 1) the objects provide a basis for developing an implementation plan, 2) a running system can be developed with flexibility for user interface, and 3) object-oriented systems allow for future upgrades without impact.

Lufkin and Metalworking Technology continue advocating innovative, yet practical approaches to help solve foundry casting design and production process problems. Phase II of the program will establish and validate the findings of Phase I.

FOR ADDITIONAL INFORMATION: To discuss this effort further, contact: Project Engineer: Siamack Mazdiyasni, Air Force Manufacturing Technology Program, ATTN: AFWAL/WL/MTPM, Wright Patterson AFB, OH 45433-6533; (513) 255-3612. Refer to contract: F33615-89-C-5708, Task 27.

Technology Assessment
U.S. Air Force

Electronic Improvements Mean Important Technology Transfer Opportunity

An effort entitled "Periodic Current Plating of Copper for Electronic Applications" is demonstrating that pulse current plating improves copper deposit material properties and produces a more uniform deposit compared to direct current electroplating technology.

Tests show significant improvements, identifying important interrelationships between process and structure properties for copper deposits. The work demonstrates that a pin hole free pulse current copper plate can be deposited without the use of additive chemistry. Test results document the mechanical process and structure property's connection. Additional efforts will further populate the matrix and expand data collection to include electrical measurements. Process control techniques for pulse current plating deposition, substrate preparation, operational limit, and property/structure properties of thin film copper foils will soon be available as part of a planned technology transfer program.

Since copper deposits are used extensively in the electronics industry, improvements will result in significant benefits for multiple programs and users. Expectations are that this process will improve the mechanical structure in conventional plated through-hole applications. From an electrical perspective, improved performance of microwave applications is also anticipated. By establishing a process-structure-property relationship, designers have access to material properties and characteristics not available today.

A unique team encourages transfer of this information. The core team consists of a technical engineering firm, Physical Science International (PSI); a university, Stevens Institute of Technology; and a plating chemical supplier, Shipley Corporation. This team is augmented by test equipment manufacturers and industry nonprofit organizations such as the Institute for Interconnecting and Packaging Electronic Circuits. Each one of these organizations has a vested interest in the success of the program and in disseminating the information. Ongoing technology transfer efforts will accelerate as the industry becomes more aware of the program's accomplishments.

The mechanisms for transferring this information are both formal, through structured meetings and reports, and informal, through ongoing discussions with government and industry associations. An industry workshop is planned to allow the interaction of industry representatives with the team members. This will be held subsequent to a closed Air Force briefing at the conclusion of the task. At the open workshop, industry will see the pulse current plating process, review test results, and conduct a peer review of the program plan. Expansion of university/industry involvement has already begun with Purdue University, Lehigh University and the National Center for Manufacturing Sciences. Presentations will also be made to the technical communities within Air Force and DoD product divisions by representatives of WL/MTE.

FOR ADDITIONAL INFORMATION: To discuss this effort further, contact: Project Engineer: Donald Knapke, Air Force Manufacturing Technology Program, ATTN: AFWAL/WL/MTE, Wright Patterson AFB, OH 45433-6533; (513)255-2644. Refer to contract: F33615-89-C-5708, Task 45.

Technology Assessment
U.S. Air Force

Quantitative Process Automation Language

Typical advanced composites for aerospace applications are materials consisting of a high strength/stiffness fiber embedded in an organic resin matrix binder. The fiber provides in-plane stiffness and strength, while the resin protects, transfers load, and stabilizes the fiber in compression. A composite structure is made by stacking plies, or layers, of composite material in prescribed directions. The laminate is then cured through the application of heat and pressure. This curing process typically takes place in a large pressure vessel called an autoclave. During the curing process an irreversible chemical reaction takes place whereby the resin is transformed from a tacky state with essentially no structural value to a single cross-linked molecule with the desired engineering properties.

Resins used for advanced composite applications are complex formulations. There are batch-to-batch variations in the mixing of the resin by the supplier. Shelflife and lay-up time at the fabricator's plant contribute to additional variations. The pre-defined cure cycles used by industry today are protracted to account for the cumulative variations possible between supposedly identical parts. The current scenario requires the time and effort of a number of engineers working together to "tweak" the control system before processing each new batch of material, and causes significant inefficiencies in production lines for parts using these materials.

To address these problems, an adaptive self-directed control system was first proposed and developed in 1986-87 under a joint Materials Lab and ManTech effort at Wright Patterson Air Force Base. The original system, called Qualitative Process Automation (QPA), used sensors located on the part to determine the state of of the resin in real time. Instead of process decisions being based on an inflexible, predetermined scenario the process pathway was determined based on the actual state of the material at the time. This allows the engineer to define the product, while the process varies to achieve that product instead of the conventional method, which can only define the process and uses historical data to show that the product will be acceptable.

Continuing activity in this area led to the development of a production hardened version of the research QPA system. The new software, Qualitative Process Automation Language (QPAL), is a complete environment for intelligent process control. Its core is a generic process control language for the encoding of process knowledge. The software is developed for an Apple Macintosh II platform. To demonstrate the applicability of this new manufacturing technology, QPAL was installed on the production floor at Sacramento Air Logistics Center (SM-ALC) and used to cure advanced composite wing leading edges for the A-10 Thunderbolt II aircraft. Tests showed that process times were reduced by 75% and the structural properties remained equivalent to conventionally cured material.

This new control system is currently being proven on the production floor at SM-ALC. The technology is being transitioned in two different directions: to other Air Logistics Centers (ALCs) and to the aerospace contractor community. Oklahoma City ALC is in the process of purchasing an autoclave with a QPA control system. Several aerospace contractors are also actively pursuing this new technology, including General Dynamics, Rohr, McDonnell Douglas, Pratt and Whitney, SAIC, and General Electric. The National Center for Manufacturing Sciences is sponsoring a program called Cure Sensing of Composites, in which Southwest Research Institute is using QPAL applied to a polyamide material called PMR-15. This effort has already reduced cure time by over 50%, and work is continuing to accommodate variations in part geometry and input material, thereby increasing flexibility in production.

Under Air Force Manufacturing Technology Directorate sponsorship, work continues on advancing intelligent process control. The next phase of the effort is to simplify the burden on the process engineer in encoding process knowledge. The engineer should not be expected to understand and communicate with the system in a language foreign to the engineer. This emphasis will facilitate the use of intelligent adaptive process control by easing the

engineering burden. QPAL software as is stands today is commercially available, and is being produced under license to the Air Force.

FOR ADDITIONAL INFORMATION: To discuss this effort further, contact: Project Engineer: Walt Griffith, Air Force Manufacturing Technology Program, ATTN: AFWAL/WL/MLIM, Wright Patterson AFB, OH 45433-6533; (513) 255-8787. Refer to contract: F33615-89-C-5708, Task 115.

Machine Tooling Makes 'Quantum Leap'

Traveling through time and changing the future are common themes for the current TV show "Quantum Leap." As a result of ManTech's Machine Tool initiative, the Air Force took a look into its future and saw a need for change. Machine tools form the heart of modern manufacturing. Our nation's machine tool industry must be strong in order for American manufacturers to compete in today's rapidly changing world markets. Looking ahead, it was apparent that inattention, limited resources and other factors were putting the U.S. manufacturers at a competitive disadvantage. The domestic machine tool industry is shrinking and imports comprise about half of machine tool purchases in the U.S. To revitalize this critical industry, several creative ideas to improve, integrate and combine processes used in the design, planning, production, and test of machine tools are now underway. The end objective is a strengthened domestic machine tool industry capable of successfully competing with foreign suppliers.

One of the Air Force's early successes is the Intelligent Distributed Measurement System (IDMS) developed under contract with Cincinnati Milacron. This effort called for Milacron to effect a reduction in machine wiring by the application of low-cost, peer-to-peer communications technology. This approach streamlined the process of sensing and providing readouts to the machine's controller, ultimately guiding the machine's motion. The optimum solution to this very complex control process is to digitize sensed parameters directly at the source, then report the data over a control network to any sub-system requiring the information simultaneously. The resulting reduction in the number of sensors and wiring minimizes the cost and complexity of cabling, improves reliability by eliminating connectors, and reduces susceptibility to noise.

After a series of trade studies, Milacron selected prototype hardware using low-cost transceiver circuits and a Controller Area Network. Protocol was developed by Bosch and is supported in silicon by Intel. Philips/Signetics and Motorola. In its prototype form, the IDMS can support up to 128 Bus Interface Units (BIUs) on a single link. Depending on the configuration of the BIUs, a link could support up to 16,384 digital Input/Output (IO) points, 1,024 resolvers, 1,024 analog outputs or some combination of these devices. An analysis of this machine shows a dramatic decrease in wiring requirements ranging from 33-54% based on wire count and 37-62% based on total wire used. The number of connectors decreased 28-49%. Most importantly, a cost-to-savings ratio of 1:3 clearly makes the IDMS hardware a wise investment. In addition, future machine designs would achieve greater cost savings by using smaller diameter flex tubes, power tracks and other wiring harness carriers.

The IDMS program has achieved its stated goal of substantially reducing machine wiring costs. Considering this is only one of several new machine tool initiatives, domestic suppliers have a bright future ahead. Combining the Air Force's vision and funding with the innovation and technical expertise of the American manufacturer, we are taking a "quantum leap" forward for the next generation of machine tools and controls.

FOR ADDITIONAL INFORMATION: To discuss this effort further, contact: Project Engineer: Paul Sampson, Air Force Manufacturing Technology Program, ATTN: AFWAL/WL/MTPM, Wright Patterson AFB, OH 45433-6533; (513) 255-3612. Refer to contract: F33615-89-C-5719.

National Center for Excellence in Metalworking Technology (NCEMT)

Navy Technology Fact Sheet

Forming Solutions for Oxygen Breathing Apparatus

Mine Safety Appliance (MSA) manufactures the A-4 Oxygen Breathing Apparatus (A-4 OBA) for the U.S. Navy. The A-4 OBA is used throughout the Navy on ships and submarines as an oxygen source for fire fighting personnel. The A-4 OBA is composed of a canister containing oxygen-generating material. The canister is manufactured from a deep drawn 1008 steel component having a kidney-shaped cross section. The oxygen-generating material contains potassium superoxide solid which releases oxygen upon combination with carbon dioxide.

Over the past several months, MSA's canister vendor has encountered wrinkling defects in the canister during the multi-step drawing process. Over 75,000 cans have been made which have enough wrinkling to make them unsuitable for use. Photograph 1 (below, left) shows a correctly manufactured canister; Photograph 2 (right) shows a wrinkled canister.

Photograph 1: Correctly manufactured A-4 OBA Canister.

Photograph 2: Wrinkled A-4 OBA Canister.

MSA contacted MTI to assist in solving the forming problem. After meeting at the subcontractor's facility to review the problem, MTI personnel analyzed and evaluated the incoming material, forming tools and the process steps.

It was determined that wrinkling results from plastic instability during deep drawing. Based on the evaluation, MTI recommended that the clearance between the punch and die be decreased so that ironing would occur to eliminate the wrinkling. Alteration of the clearances to introduce ironing will be necessary to preclude this wrinkling in future cases. MSA is currently evaluating vendors wishing to incorporate the suggested recommendations.

FOR ADDITIONAL INFORMATION: To discuss this effort further, contact: Dr. Robert E. Swanson, Director, Process Technology through the National Center for Excellence in Metalworking Technology, 1450 Scalp Avenue, Johnstown, PA 15904; (814) 269-2530.

National Center for Excellence in Metalworking Technology (NCEMT)

Navy Technology Fact Sheet

Plasma Spray Initiative

A project of major importance in the Navy's Manufacturing Technology Program is the Plasma Spray-CNC Workcell initiative being carried out by the National Center for Excellence in Metalworking Technology (NCEMT). Plasma spray repair consists of spraying a powdered surfacing material through a high-energy plasma plume onto a damaged area of the part to be refurbished. The powder strikes the part surface in a molten state and forms a mechanical bond with the surface. The sprayed part is then machined to original specifications. The economic benefits of this repair technique have been demonstrated through extensive application.

Each year Naval Maintenance Activities repair and refurbish several thousand parts through the application of manual plasma spraying and finishing procedures. Repaired surfaces on these parts often perform better than the original equipment in terms of wear, erosion, and corrosion resistance. In many cases the parts can be repaired at a fraction of the new part price. Repairs can be made in a matter of days compared with replacement times which can extend for months. However, present process controls and quality assurance are dependent on the operator. Procedures require a high level of operator skill and concentration. Operator fatigue and subjective technique can detract from overall cost effectiveness and final part quality. Also, there is a great deal of time and effort expended in the current process due to multiple part setups and relocations.

The Plasma Spray-CNC project involves integration of known and developing technologies into a unique, automated workcell. The primary goals are to: Develop an automated system that integrates thermal spray process control, part preparation, part finishing, and quality assurance; Demonstrate repair capabilities of automated integrated thermal spray systems; Transfer automated thermal spray technology to the domestic repair and maintenance community.

The program plan calls for the development of an integrated Plasma Spray-CNC Workcell. The integrated workcell approach will produce multiple benefits: Process controls will no longer be dependent on varying operator skills and fatigue; Overall parts quality and consistency will improve; Operator training requirements and skill levels will be reduced drastically; Process planning will be automated, reducing the engineering support required for these procedures; Scrap levels of defective parts will be reduced; Setup and relocations times will be greatly reduced; Utilization of this repair technique will be expanded.

Overall program management and coordination is provided by NCEMT. The David Taylor Research Center is providing technical support in process standards and testing. Puget Sound Naval Shipyard (PSNS) is contributing process experience and procedure testing, and will be the initial customer of the integrated system. Currently, the majority of the work on this program is in pursuit of the first goal - the development and integration of the system. When this development work is complete, a three-month demonstration phase will commence at MTI (currently scheduled to begin in May 1992). The workcell is then slatted for transfer and re-installation at PSNS in Bremerton, WA. A six-month demonstration period at PSNS is the final phase of the planned program. The workcell will then continue to operate at PSNS as a production unit once the demonstration period is complete.

Thermal spray part repair techniques are applied to parts of many different shapes. However the majority of parts repaired at PSNS are cylindrically shaped-pump shafts, blower shafts, valve stems, etc. For this reason the workcell has been designed to manipulate cylindrical parts only. The part manipulator is a vertical bed turning center (lathe) with a capacity for 15" diameter shafts up to 6' long. Once the part is setup on the lathe, the damaged area will be removed with traditional tooling. Surface preparation will be applied by a grit blast gun manipulated as another tool on the CNC tool turret. The spray buildup operation will then be performed with a plasma gun also manipulated by the turret, and the sprayed area will be remachined back to original size and finish by the CNC tooling.

The integration of these process steps on a CNC lathe is an extremely difficult and complex task. Grit-blasting and plasma spray guns are not used today as tools in machining centers. Abrasive particle contamination of the machine tool, hose/cable manipulation, and gun pickup/release are major areas of design activity. Also, the plasma

coatings (which may include ceramics) are currently finished by grinding operations; the workcell, however, is designed with single point tooling. A major investigation is underway which will allow newer tool materials, such as poly-crystalline diamond (PCD), to finish these materials without grinding. Preliminary results are encouraging. This technology is expected to allow the part to be completely repaired with only one setup instead of the four or more used in manual procedures today.

The major equipment components to be integrated in this system include a vertical bed turning center, grit blaster, DC plasma thermal spray unit, a dust collection unit, and a cell control computer. The majority of the equipment will operate inside an acoustical enclosure. The enclosure is necessary since the plasma operation emits noise levels around 120dB (acceptable OSHA limits for an 8 hour shift are under 90dB). The dust collection unit is required to remove blasting grit, smoke, heat, and powder overspray from the operation.

The components of the workcell will be controlled through the cell control computer, which will automate the repair process planning and execution. The process planning portion of the system will have the capability to run in a "stand-alone" mode, in order to produce a process plan (job control record) and quality assurance documentation for use with separate thermal spray and machining equipment. The stand-along planner is intended for use in an existing military Intermediate Maintenance Activity (IMA) and small commercial shop environment. Along with the cell and planner hardware, the program will produce an acquisition data package to allow multivendor competition for producing industrially hardened workcells in the future.

The platform selected by Navy personnel for the workcell controller is PC compatible. This will allow the stand-alone planner software to be disseminated and utilized on a broad basis with minimal Navy investment. The PC, however, is not the ideal platform for performing real-time, multi-tasking equipment control. Both the turning center and the plasma spray unit have their own integral real-time controls built in. The system, therefore, is being designed to that the cell controller assembles the appropriate CNC programs and spraying parameters, downloads them to their perspective controllers, commands execution start, and then takes on a monitoring role with the CNC machine handling the execution master control. In today's typical robotic plasma spray cells, the robot control sequences the spray system on and off and selects what coating parameters are active. Since the turning center has a CNC controller similar to those in robot applications, this portion of the control is not significantly different from other applications. The large deviations from common use lie in the fact that the surface preparation, plasma spray, and surface finishing all occur within a single machining center. Also, the cell controller operator interface, automatic planning, and scheduling/execution are major differences from common repair applications today.

The software development component of the Plasma Spray-CNC Workcell is also a major undertaking. Considerable customization will be performed in both the CNC and Plasma Spray controller software to allow real-time coordination and controller communication. The workcell controller is responsible for accepting operator entered job, part, and process information. Tabulated rules and guidelines are applied to automatically produce a part repair plan including information such as: undercut depths, tool selections, spray coating process selections, coating thickness determinations, application parameters, actual CNC code, and finishing techniques. Extensive software design and development work is being focused on the cell controller. Efforts are underway to make the operator interface intuitive so that users will require little training. The software design is being implemented through object oriented techniques with modularity and extensibility in mind. One of the goals in this development is to allow incorporation of new processes or hardware with as little overall software modification as possible.

The Plasma Spray-CNC effort involves a very sophisticated integration of expertise from many diverse disciplines including: mechanical, electrical and software engineering, material science, process control, communications, CNC machining, etc. Currently, all required process investigations are either complete or well under way. The majority of significant equipment components have been specified, quoted, and ordered (or are in the purchase approval process). Great efforts are being expended on software development and mechanical/electrical integration designs. During early 1992 the components of the workcell will be assembled, tested, debugged, and readied for demonstration. These months are expected to be busy ones for the entire Plasma Spray-CNC Workcell development team.

FOR ADDITIONAL INFORMATION: To discuss this effort further, contact: National Center for Excellence in Metalworking Technology, 1450 Scalp Avenue, Johnstown, PA 15904.

National Center for Excellence in Metalworking Technology (NCEMT)

Navy Technology Fact Sheet

One-Dimensional Casting Model Addresses Mold Design Details

At the request of the Philadelphia Naval Ship Yard, NCEMT conducted a thermal analysis of mold designs used for large castings. The principle objective was to determine the time for a chill to become saturated with heat and lose its effectiveness.

Since heat flow to the chill is a localized effect, a one-dimensional heat transfer model was developed. The model determines the effects of several mold design variables on the cooling rate of a casting in the vicinity of a chill.

The casting model gives the following results: Chill thickness has a significant effect on solidification time up to a chill thickness equal to that of the casting (Figure 1, left). Layered chills only affected solidification time when the individual chills are thinner than the casting. Layered chills do not offer the same effect as a single chill of equal thickness. Zircon mold wash thickness had a dramatic effect on the solidification time (Figure 2, right), while the backing sand thickness made little difference on the solidification time. Iron chills offer a milder and more sustained chilling effect than do copper chills. Finally, the thickness of sand placed between layered chills affected the solidification time dramatically.

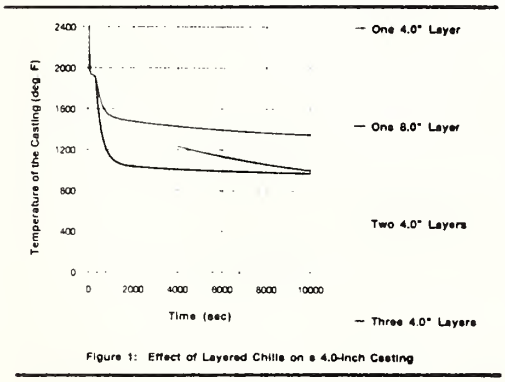


Figure 1: Effect of Layered Chills on a 4.0-Inch Casting

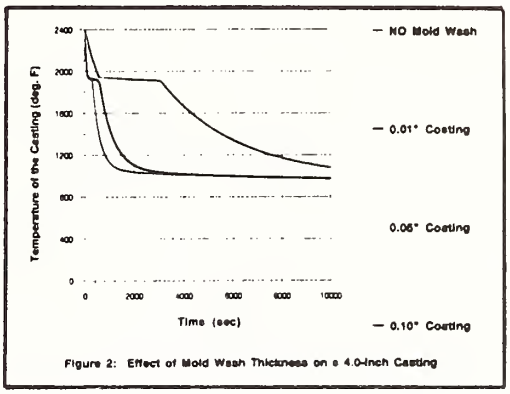


Figure 2: Effect of Mold Wash Thickness on a 4.0-Inch Casting

The computer model used in the thermal analysis is designed to handle a wide variety of casting and mold materials. It will operate on a personal computer with typical run times of less than one minute. As a result, the model can serve as a production design tool by foundry engineers.

FOR ADDITIONAL INFORMATION: To discuss this effort further, contact: Michael Tims, National Center for Excellence in Metalworking Technology, 1450 Scalp Avenue, Johnstown, PA 15904; (814) 269-2515.

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

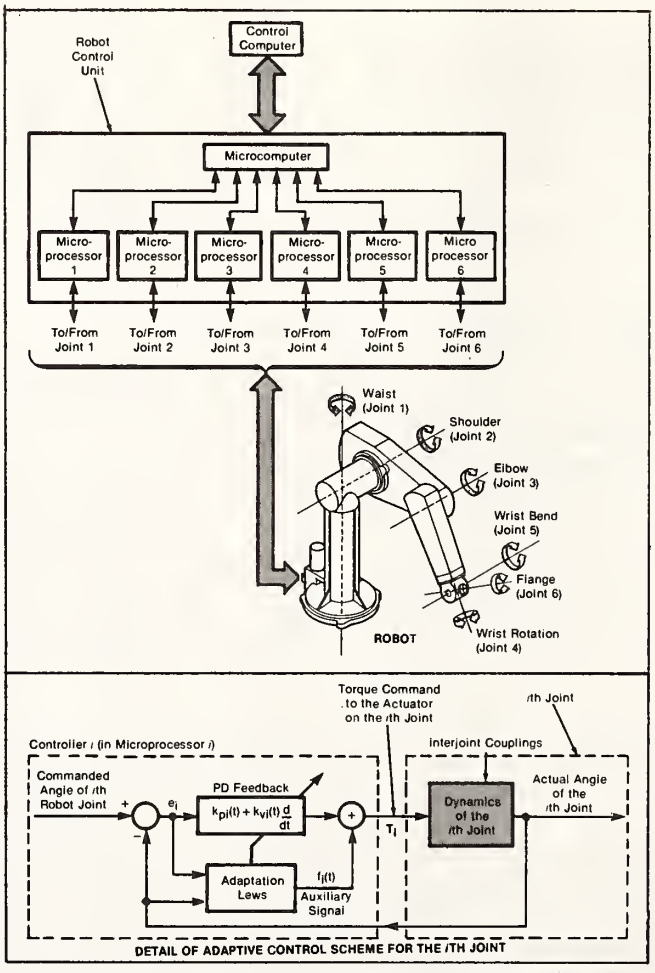
Direct Adaptive Control of an Industrial Robot

Desirable features include fast sampling and accurate tracking of the commanded trajectory.

A decentralized direct adaptive control scheme for a six-jointed industrial robot has been demonstrated in the JPL Robotics Research Laboratory. In this scheme, each joint is controlled via a local feedback controller at a high sampling rate. This largely decentralized scheme eliminates that part of the overall computational burden that would be imposed by a centralized controller and that would degrade the performance of the robot by reducing the sampling rate. In the experimental system, the sampling and computation cycle is only 7 ms long.

The higher and intermediate-level functions of the control algorithm (e.g., planning trajectories, evaluation of actual trajectories, and communication of control information to and from the robot) are executed by an external digital control computer. Another computer that is part of the robotic equipment acts as an input/output device between the external computer and the joint motors; this computer includes (1) one microprocessor that serves as the local controller for each of the six joints and (2) a microcomputer that passes data and commands back and forth between this computer and the external control computer (see figure).

The adaptive feedback controller for each joint implements a proportional/integral/derivative position-control algorithm with position/velocity feedback and with gains updated in real time. The adaptive feature of the local control law implemented by each joint controller compensates for any static and dynamic cross-couplings between that joint and the other joints and contributes to accurate tracking of the commanded trajectory. When all joints move rapidly simultaneously, the interjoint couplings can sometimes cause instabilities under the decentralized control scheme. In such cases, the controller-adaptation laws are modified slightly to obtain stability in the presence of unmodeled cross-coupling effects.



The **Decentralized Adaptive Controller** includes a separate feedback controller for each robot joint. The controller is robust in the face of unmodeled dynamics and provides accurate tracking of commanded trajectories, with a short sampling period.

The control and controller-adaptation laws are based entirely on the observed performance of the manipulator: there is no need to model the dynamics of the robot; nor is there any need to specify the inertial parameters of the payload. Thus, the adaptive controllers can cope with uncertainties and variations in the robot and the payload, including friction (which cannot be modelled accurately) and the mass of the payload (which can vary substantially).

This work was done by Homayoun Seraji and Thomas Lee of Caltech and Michael Delpech of the Centre National d'Etudes Spatiales for **NASA's Jet Propulsion Laboratory.**
NPO-17964/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center, Houston, Texas

Licensing Opportunity

Fastener for Hot, Oxidizing Environments

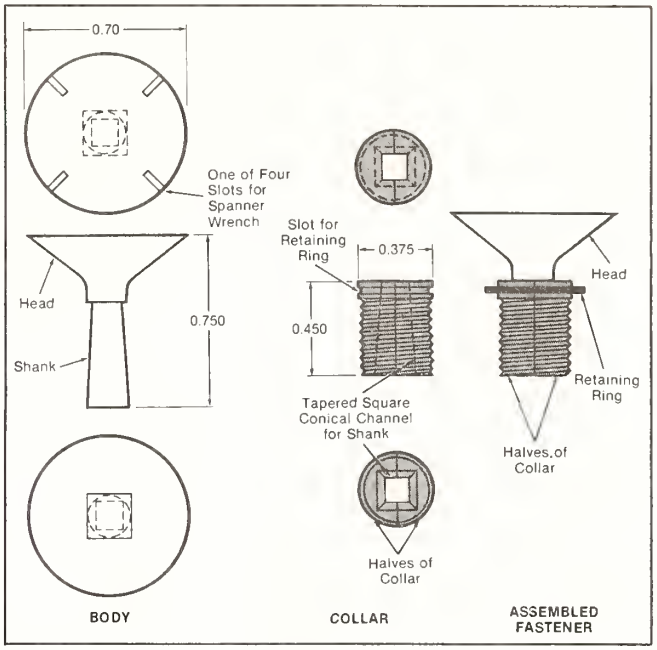
It can be assembled and disassembled quickly from the outside.

A threaded fastener is designed for service at extremely high temperatures in oxidizing atmospheres. The fastener consists of four parts (see figure). The body—a head with a tapering shank—is made of a high-temperature-resistant composite material and has a ceramic coat to protect it from oxidation. A collar, composed of two halves with continuous external threads, is made of a strong refractory metal alloy. The two halves are fitted onto the shank and secured to the shank by a lockring.

The fastener is inserted in a hole in the panel to be fastened until the conical surface of the head makes contact with a similar conical surface countersunk in the hole. The threaded halves are then secured on the shank. A screwdriver, spanner wrench, or other suitable tool is inserted in a slot or slots in the head to turn the fastener in a threaded receptacle behind the panel. When the fastener is fully tightened, the top of its head is flush with the surface of the panel.

Note that the cross section of the shank is not circular but square. This geometry enables the body to grip and turn the threaded collar instead of merely sliding within it.

The ceramic coat that gives the body of the fastener its resistance to oxidation is brittle; if subjected to tension or shear, it would crack and the fastener would quickly oxidize and fail. The taper on the shank transforms the shear and tension from the threads in the collar into a combination of radial compression and axial tension in the shank (which the shank can withstand readily). In turn, the conical taper in the head assures that the ceramic coat is stressed mainly in compression, which it can withstand readily.



Threaded Halves of the metallic collar fit around the tapered shank of the body of the fastener. A retaining ring holds the collar on the body. Dimensions are in inches.

This work was done by Thomas J. Dunn of **Johnson Space Center.**

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center. Refer to MSC-21580/TN.

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FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE :

NASA Tech Brief
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center, Houston, Texas

Licensing Opportunity

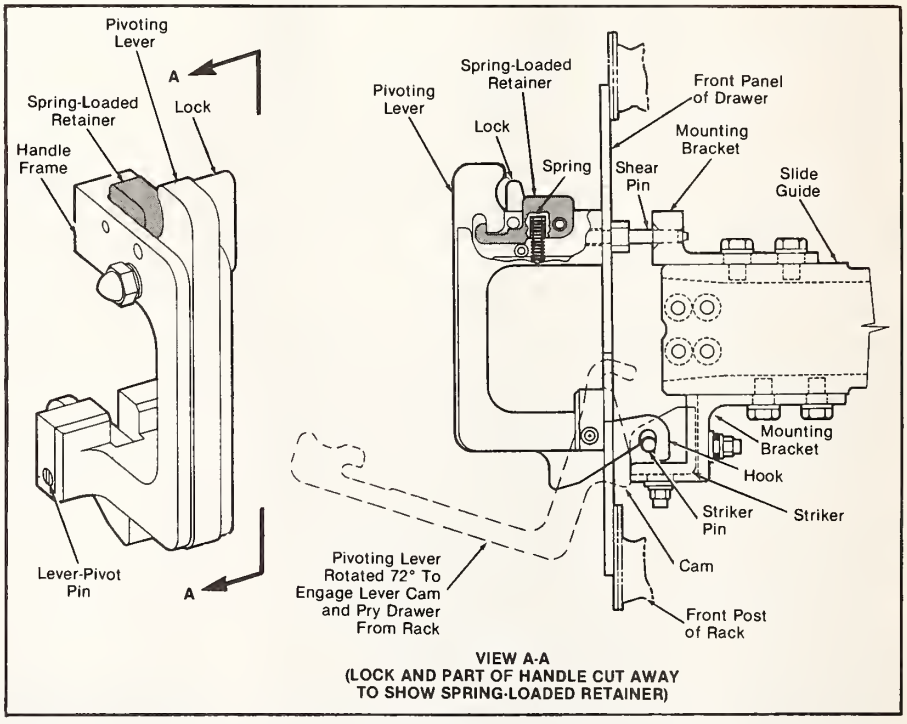
Latches for Equipment Drawers

A mechanism makes rack hardware interchangeable, regardless of drawer height.

A pair of panel-handle latches provides quick connection and disconnection of an equipment drawer in a rack. The latches enable the interchange of drawers of different heights without alteration of the fittings on the front of the rack. They provide load-carrying capacity in three orthogonal directions, press the front panel of the drawer flush against the rack, and establish electrical grounding paths between the panel and the rack.

A rotating latch is built into each of the two handles on the front panel of a drawer. When a user pushes the drawer into a rack, a hook on a pivoting lever on each latch becomes positioned over a pin in an adjustable striker assembly (see figure). At the same time, a shear pin at the top of the handle engages a mounting bracket on a slide guide in the rack. The user rotates the lever so that the hook engages the striker pin and pulls the front panel of the drawer flush with the front surface of the front post of the rack. The user continues to rotate the lever into the handle frame, where it is latched and closed by a spring-loaded retainer in the handle. The user then secures the drawer by rotating a lock into its closed position.

To remove the drawer, the user rotates the lock into its open position, presses the locking retainer down, and rotates the pivoting lever downward until its cam hits the striker assembly. Additional downward force on the lever causes the cam to pry the drawer loose from the rack and from any mating mechanical and electrical connectors.



VIEW A-A
(LOCK AND PART OF HANDLE CUT AWAY TO SHOW SPRING-LOADED RETAINER)

The **Pivoting Lever** is the heart of the latching mechanism. At insertion, the lever is rotated slightly counterclockwise so that its bottom hook can slip over the pin; it is then rotated clockwise to engage the pin and the lever lock. Rotation of the lever to the full counterclockwise position disengages the panel from the rack.

The latch requires little or no maintenance. All parts that rotate are equipped with bushings on fixed pins, so that wear should be low and reliability high.

This work was done by T.C. Martin of General Electric Co. for **Johnson Space Center.** *MSC-21756/TN*

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NASA Tech Brief
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center, Houston, Texas

Leak Stopper for Metal-to-Metal Tube Fittings

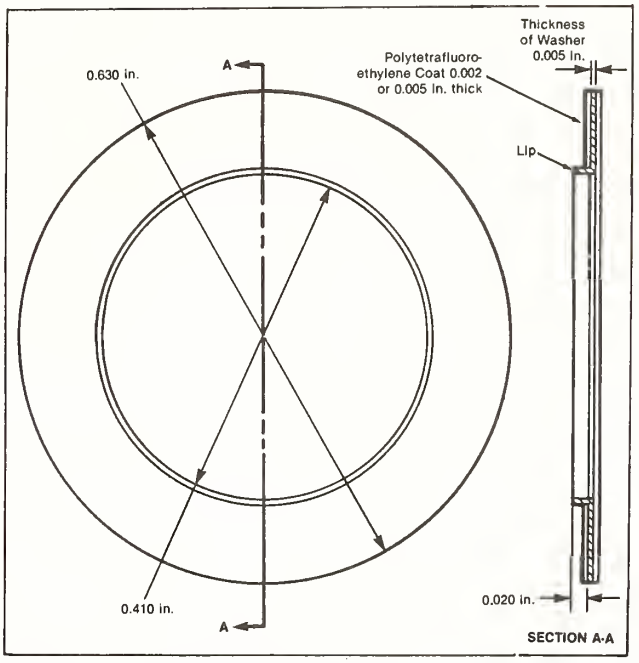
A plastic-coated steel device is both conformal and strong.

A washerlike seal stops leakage at Dynatube™ joints between metal tubes. The seal is made of materials that resist attack by corrosive and oxidizing fluids. In addition, the seal aligns itself in the joint for maximum effectiveness.

The seal is a thin stainless-steel washer that includes an inner lip and that is partly coated with polytetrafluoroethylene (see figure). The inside diameter of the washer is about the same as that of the Dynatube fitting, and there is a slight interference fit between the lip and the inner diameter of the Dynatube fitting. The seal is therefore press-fit or snapped in place in fitting and stays there, regardless of the orientation of the fitting.

The polytetrafluoroethylene coat adheres well to the surface of the stainless-steel core. The core provides strength, while the polytetrafluoroethylene coat provides the soft material to flow into scratches on the fitting and forms the seal. Seals for 1/2-in. (12.7-mm) fittings have been fabricated. Seals for 1/4-in. (6.35-mm), 5/8-in. (15.88-mm), and 3/4-in. (19.05-mm) fittings have been designed. The stainless-steel core is nominally 0.005 in. (0.127 mm) thick. Polytetrafluoroethylene coats 0.002 in. (0.05 mm) and 0.005 in. (0.13 mm) thick have been manufactured and tested. Other thicknesses of polytetrafluoroethylene may be used, depending on the size of the leak in the fitting. The lip is offset 0.020 in. (0.51 mm).

This work was done by Joseph R. Trevathan of **Johnson Space Center.**
MCS-21800/TN



The **Plastic-Coated Washer With Lip** fits securely in a leaky fitting. Typical dimensions for a 0.5-in. (13-mm) seal are shown.

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

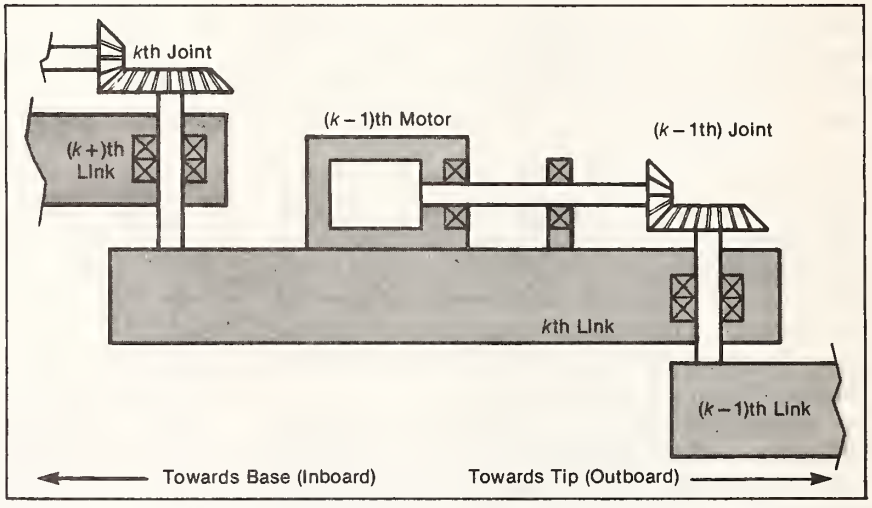
Recursive Algorithms for Dynamics of Geared Robots

Inertias of motors and gears are taken into account.

Improved recursive algorithms compute the dynamics of a robotic manipulator driven through gears by motors located away from the joints. These algorithms are intended to replace prior algorithms that implement direct-drive mathematical models, in which drive motors are considered to be located at the joints and to behave as ideal actuators.

The direct-drive models are inadequate to address the more-complicated dynamics of gear-driven manipulators, in which the rotational inertias of the motors are amplified by the gear ratios and can sometimes even dominate the dynamics. Reliance on a direct-drive model can lead to significant errors in the design of the control system of a manipulator, with consequent degradation of the stability and performance of the robotic system.

The development of the improved algorithms began with the Newton–Euler equations of motion of a manipulator, specialized to the case in which each joint has one degree of rotational freedom and the motor and gears that drive each joint are mounted on the inboard link of the two links connected by that joint (see figure). These equations were used to obtain a mass matrix and Coriolis terms. The mass matrix is more complex than it would be in the corresponding direct-drive model; it includes additional diagonal and off-diagonal terms that represent the additional cross-coupling between joints that is attributable to the inertias of the motors.



The **Rotation of Each Link** of the manipulator arm about a joint at its inboard end is driven by a motor and gears mounted on the adjacent inboard link.

A recursive algorithm that computes the mass matrix and that involves a number of arithmetic operations approximately proportional to n^2 (where n is the number of links) was derived by use of the spatial-operator algebra discussed in a previous article in *NASA Tech Briefs*. New operator factorizations of the mass matrix and expressions for its inverse were obtained. Building on the foregoing, a recursive forward-dynamics algorithm that requires a number of arithmetic operations approximately proportional to n was derived.

Despite the additional complexity of the dynamical models of the geared manipulator, the mass-matrix and forward-dynamics algorithms for geared manipulators closely resemble the corresponding algorithms for direct-drive manipulators and require a relatively small amount of additional computation. Consequently, present direct-drive algorithms can be extended easily to gear-drive cases.

This work was done by Abhinandan Jain and Guillermo Rodriguez of Caltech for **NASA's Jet Propulsion Laboratory**. *NPO-18230/TN*

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Materials

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0675 Computer Codes Predict Stresses on Parts in Manufacturing

0676 Color Changing Paint

0677 Atlas of Formability for Understanding Material Characteristics

Testing & Instrumentation

0678 Deformation Test System Upgraded for Very High Temperature Deformation

Software

0679 Finite-Element Program for Analysis of Cracked Bodies—ZIP3D analyzes elastic, plastic, and fracture behavior.

0680 Program Analyzes Crack-Growth Data—This program processes data from cyclic crack-growth tests.

Other Items of Interest

0663 Electronic Improvements Mean Important Technology Transfer Opportunity

0664 Quantitative Process Automation Language

0666 Forming Solutions for Oxygen Breathing Apparatus

0668 One-Dimensional Casting Model Addresses Mold Design Details

Lawrence Livermore National Laboratory

Light-Gas Gun and Buckyballs

Researchers at Lawrence Livermore National Laboratory (LLNL), who have used a powerful gun to turn graphite into diamonds, flatten buckyballs into graphite and glassy diamond, and simulate a meteorite crashing into the Earth, are now aiming to help make American industry more competitive.

The powerful tool they're using is a two-stage, light-gas gun. Measuring just 20 feet in length, the gun is able to hurl small plastic projectiles at speeds up to four kilometers per second, about 9,000 mph. At such speeds the impact creates tremendous shock pressures and temperatures, which can dramatically change the structure and properties of the material being targeted.

While shock experiments in the United States have been conducted almost exclusively as part of defense research, in Japan they are used in industry.

"Japanese scientists have taken shock wave techniques developed in the U.S. for military research and are using them almost entirely for developing commercial materials, such as ceramic oxides for high-temperature engines and hard materials for cutting tools," said Bill Nellis, who heads both the Shock Physics Group in the Laboratory's H Division and the High Pressure Center in the University of California's Institute of Geophysics and Planetary Physics.

"Now that the Laboratory and the Department of Energy are looking to transfer technology to American business, this gun opens up a lot of possibilities," Nellis added.

The results of an experiment of LLNL, shocking carbon fullerences or "buckyballs," were published in the Dec. 6 issue of *Science*. Recently discovered buckyballs are hollow soccer-ball-shaped molecules made up of 60 or more atoms. Now the subject of intense research, buckyballs are being examined by scientists looking at applications ranging from superconductors to lubricants to reinforcing materials.

"The key question is how strong are they?" Nellis said. "We wanted to know what pressures and temperatures they can withstand. Eventually they do break and we wanted to see what form they would take."

The experiments used 0.1-millimeter-thin layers of buckyballs (the thickness of a sheet of paper) weighing 10 milligrams (the weight of a circle of kitchen foil half-an-inch in diameter) sandwiched by copper. The gas gun was used to subject them to pressures ranging from 100,000 to one million times the atmospheric pressure on Earth at sea level (equal to 1 bar).

In a thin layer, shock pressure decreases at a trillion bars per second and shock temperature at a billion degrees per second, freezing in forms made at high pressures.

While scientists elsewhere are studying buckyballs at high static pressures, phase changes have not been reported using other methods, Nellis said. Learning how buckyballs react under different situations can help find practical uses for the material.

The new gas gun allows private firms to conduct materials research once possible only with explosives, which have not been readily accessible at remote firing sites and normally use much larger specimens. The gun makes shock physics an "indoor sport" and facilitates new applications, Nellis said.

In another recent experiment, Dave Erskine of H Division observed graphite transforming into diamond in 10 billionths of a second. The technique permits controlling and optimizing the making of materials at high pressures.

These experiments showed that the nature of the graphite and its orientation are key factors in diamond synthesis. Japanese industrial researchers have recently applied the results of these physics experiments to shock-synthesize diamond powder with 10 times the crystal size as produced in the U.S.

The Laboratory researchers believe the gas gun has applications in physics, chemistry, materials science, geology, and engineering.

"Many firms in the United States are unaware of our capabilities because the work has been done in relative isolation at defense laboratories," Nellis said. "We want to use the gun to knock down that isolation. We're looking to collaborate with industry on their materials problems."

FOR ADDITIONAL INFORMATION: For more information, contact Charles Miller, (510) 423-3082.

Sandia National Laboratory

Computer Codes Predict Stresses on Parts in Manufacturing

Computer codes for the analysis of structures are helping researchers at Sandia National Laboratories predict a part's response to manufacturing processes, without using time-consuming and expensive experimental techniques.

These codes, using mathematical descriptions of material response, predict the stresses and strains that can occur during production. High-quality parts cannot be produced nor can optimum fabrication processes be chosen unless such events are understood.

"A manufactured part often undergoes more severe conditions during its production than it ever sees in service," says John Biffle, supervisor of Sandia's Computational Mechanics and Visualization Division. "The goal is to eliminate process-induced problems before they happen."

Manufacturing processes such as welding, forging, sheet forming, brazing, casting and injection molding, subject materials to a wide variety of stresses and strains that can weaken or deform a finished part. Microscopic cracks, shrinkage and residual stresses—loads left inside a material after processing—can occur, which can reduce a part's lifetime or performance. Some parts do not even survive the production process.

Designers commonly rely on prototype development and traditional experimental techniques to develop a production process for manufacturing parts and components. But these trial-and-error techniques can be expensive and time-consuming, especially for complex parts designed to tight specifications. Fluctuations in process variables often lead to costly rework when their effect on the manufacturing process is not understood and there is no real-time process control.

Advances in computational mechanics and mathematical models of material behavior are allowing Sandia analysts in Albuquerque and Livermore to predict a part's response to manufacturing processes before anything is constructed.

Developers write the programs in modular form so that new features can be incorporated as more detailed process models become available. Visualization software is used for graphical data presentation to assist the analysts in interpreting and understanding the results from the numerical models.

PRONTO3D is a code developed at Sandia that can be used to analyze the large deformations and strain rates associated with sheet metal forming.

JACQ3D, a thermal code, and JAC3D, a structural code, were used in developing a cylindrical battery to determine what kind of heat sinks were necessary.

Depending on the process and the material being analyzed, current computer modeling is able to significantly reduce the time for prototype development. However, it is believed that advanced computing capabilities could be applied to real-time manufacturing process control.

FOR ADDITIONAL INFORMATION: Technical Contacts: John Biffle (505) 844-5385 and Mel Callabresi (510) 294-2064, Department of Energy, Sandia National Laboratories, Albuquerque, NM 87185-5800.

U.S. Navy Technology Application

Naval Civil Engineering Laboratory

Color Changing Paint

The Naval Civil Engineering Laboratory has developed pigment complexes that change color as a function of temperature. These reversible thermochromic pigments can be used in paints, plastics, inks and other related formulations. The primary purpose of the pigments is for energy conservation through absorption and reflection of sunlight. When a building is shaded or the sunlight is weak, the roof color is dark. When the sunlight is direct and intense, the dark color becomes lighter and eventually white, to reflect the solar heat.

The pigments can be used in roofing materials, to absorb and reflect heat. These pigments can also be used in inks, plastics and other polymer based materials in which a temperature induced reversible color is desired. Colors available are: a) blue to white; b) black to white; c) green to yellow; d) red to white; e) orange to yellow; f) orange to white; and g) green to white. Temperature transitions are available at nearly any temperature between -10 degrees C and +90 degrees C.

For more information, contact Jerry Dummer, (805) 982-1599.

National Center for Excellence in Metalworking Technology (NCEMT)

Navy Technology Fact Sheet

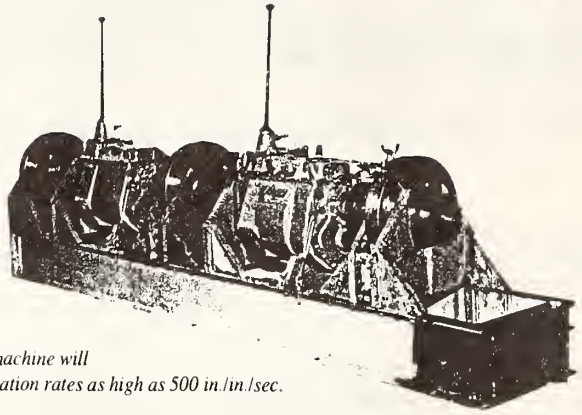
Atlas of Formability for Understanding Material Characteristics

Throughout metalworking's long history, the processing of materials has been based on prior experience and conducted principally through the trial-and-error process. In today's world of advanced technology, the requirements for higher performance and better product quality have created the need for precisely controlled manufacturing processes. The historical trial-and-error method is incompatible with this need due to the high cost and extended time involved. To regain a competitive edge in the world market, the U.S. industrial base must use integrated approaches to control the precise manufacturing methods required to quickly and efficiently process existing and newly developed high performance materials. One such approach is MTI's Rational Product & Process Design ($R \cdot P^2 \cdot D^{SM}$) methodology, the subject of prior *Updates*.

Fortunately, advances in high speed computing, numerical analysis and modeling techniques are making these goals more readily achievable. However, to fully realize the benefits of applying these technologies, material behavior during actual processing conditions must be fully understood. The NCEMT has established an ongoing project entitled Atlas of Formability. The Atlas is providing the Navy, its vendors, and the domestic metalworking industry with a compendium of data describing the mechanical behavior of advanced material during actual processing conditions. These data include flow stress, forming efficiency, post-processed material characteristics, and forming limits. The Atlas also includes process optimization "know-how" to guide the user in the application of the data.

A state-of-the-art Metalworking Laboratory consisting of two components - a unique Materials Testing Laboratory and an advanced Metallographic Laboratory - has been developed to support the Atlas and other NCEMT programs. The Materials Testing Laboratory provides useful information on the effects of temperature, rate of deformation, and other processing parameters on the flow stress and workability of materials undergoing plastic deformation. The Metallographic Laboratory provides knowledge of the microstructural evolution taking place in the material during forming processes. Although the Metalworking Laboratory has been operational for three years, methods and procedures continue to be improved and updated to assure state-of-the-art capabilities in these rapidly evolving technologies.

Test conditions in the Materials Testing Laboratory conform to actual processing parameters used by industry, thereby assuring process optimization and realistic transfer of results to industry. Mechanical properties under investigation include: stress-strain relations at elevated temperatures and various strain rates, workability, forming limits, and strain to fracture. The Metallographic Laboratory provides information that is used in predicting defect formation and accumulation during processing. By combining knowledge of mechanical behavior and microstructural evolution, process parameters can be optimized, thereby providing the ability to produce defect-free products with desirable microstructural and mechanical properties.



Photograph 1: Cam Plastometer.
When redesigned completely, this machine will
simulate hammer forging at deformation rates as high as 500 in./in./sec.

The Cam Plastometer (Photograph 1) is a very high speed compression testing device that can simulate forging at deformation rates as high as 500in/sec. This machine was originally constructed for Los Alamos National Laboratory and is the only one of its kind in the United States. It is currently being rebuilt for elevated temperature testing at temperatures up to 1,500 C and for load capacities to 100,000 lb.

Future Atlas chapters containing comprehensive information on a wide variety of materials will be available to the public via technical bulletins. The results will also be presented at technical conferences and in published papers. In addition, an implementation methodology to use the data to optimize existing forming practices as well as first-time process designs will be provided. This methodology will be applicable to the wide range of materials incorporated into the Atlas, including present day Navy materials, new generation intermetallic compounds and future generation intermetallic matrix composites.

The Atlas data will be utilized to evaluate and optimize existing metalforming processes, and more importantly, to design future "right-the-first-time" metalforming processes. The material flow behavior data in the Atlas are critical for the successful application of advanced analytic tools, such as finite element modeling (FEM). The distribution of material flow parameters at different stages of the forming process predicted by FEM can be compared with flow stability, forming efficiency, microstructure, workability, and other characteristics available in the Atlas. This analytical optimization of process parameters allows engineers to avoid the costly and time consuming trial-and-error methods for developing these advanced processes.

In the case of "first time" process design, a strain-rate/temperature "window" may be selected from the Atlas to assure successful processing, etc. Using the material flow data from the Atlas within this window, an FEM simulation of the forming process under consideration can be performed using commercially available finite element codes such as DEFORM and ABAQUS. Several of these simulations can be run for varying process parameters (e.g. die and workpiece temperatures, die geometry and lubrication, etc.). The results of these runs will identify the optimal process parameters that ensure the desire product quality.

Ongoing since October 1989, the Atlas of Formability program is focused on providing industry with the best state-of-the-art metalworking data. Many suppliers to Navy, Air Force, Army, and commercial industry are participating in the program by providing materials for evaluation. This program has great potential for making a major impact on the domestic metalworking industry by providing the necessary technological data manufacturers need to become global leaders.

FOR ADDITIONAL INFORMATION: To discuss this effort further, contact: National Center for Excellence in Metalworking Technology, 1450 Scalp Avenue, Johnstown, PA 15904.

National Center for Excellence in Metalworking Technology (NCEMT)

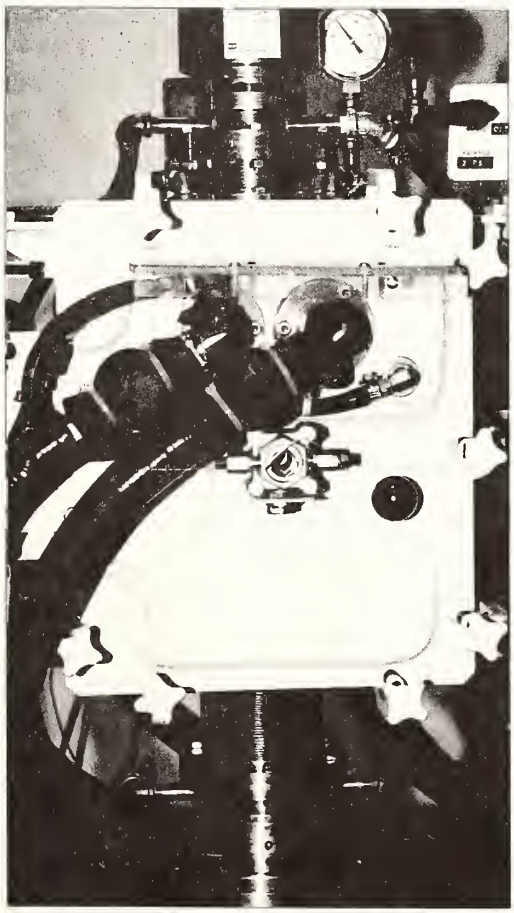
Navy Technology Fact Sheet

Deformation Test System Upgraded for Very High Temperature Deformation

MTI's Deformation Testing System has been substantially enhanced. The upgraded capabilities are being used to support MTI's efforts on behalf of NCEMT and other clients, and offers specialized capabilities for testing materials at very high temperatures and deformation rates.

Using the enhanced Materials Test system (MTS), the behavior of high strength complex alloys such as intermetallic and metal matrix composites, superalloys and ceramics can be better understood at both forming and service temperatures. Material systems, which oxidize in air can be tested in vacuum or argon gas environments. Additionally, the system can be used to heat-treat laboratory scale specimens and to understand microstructural evolution during deformation of materials.

Specimen undergoing compression at high temperature.



The high temperature environmental testing chamber.

MTI enhanced the System in several ways. First, the MTS was equipped with an environmental furnace. The furnace allows the specimen chamber to be operated at temperatures up 2500 C in a vacuum or an inert atmosphere. In addition, the furnace can maintain temperature stability within 1 C. Second, a variety of tooling materials are being used to perform compression and bend tests at temperatures up to 2000 C. These materials include: TZM, graphite, tungsten carbide and silicon carbide. Finally, the System now allows for rapid quenching in argon, after deformation, at rates as high as 500 C/min. These enhancements are currently being used to help MTI improve its ability to understand, model, and apply advanced thermomechanical treatments.

FOR ADDITIONAL INFORMATION: To discuss this effort further contact: National Center for Excellence in Metalworking Technology, 1450 Scalp Avenue, Johnstown, PA 15904.

Finite-Element Program for Analysis of Cracked Bodies

ZIP3D analyzes elastic, plastic, and fracture behavior.

ZIP3D is an advanced finite-element computer program developed for the analysis of cracks in three-dimensional elastic or elastic/plastic bodies. The program calculates mixed-mode fracture-mechanics parameters in cracked solids. However, bodies without cracks can also be analyzed to obtain stresses, strains, and displacement fields.

ZIP3D uses eight-node isoparametric elements and small-strain deformation theory. A special reduced-shear integration scheme is provided for bending-dominant problems. The elastic/plastic analysis is based on the incremental plasticity theory using the von Mises' yield criterion, isotropic hardening, and Drucker's flow rule. The initial-stress algorithm is used in this analysis. Three types of material stress/strain curves can be modeled: elastic/perfectly plastic, Ramberg–Osgood, and multilinear representations.

Some unique features of ZIP3D are: (1) the computation of mixed-mode strain-energy-release rates for elastic solids using a three-dimensional virtual-crack-closure technique, (2) the calculation of the J-integral for elastic and elastic/plastic materials by use of the equivalent-domain-integral method, (3) the capability to extend the crack under monotonic or cyclic loading, and (4) the capability to close or open the crack faces during cyclic loading.

ZIP3D is written in FORTRAN V for batch or interactive execution on the CRAY-2, CRAY X-MP and CRAY Y-MP series computers running a UNICOS operating system. Analysis of large models can require as much as 16M words of memory. ZIP3D is distributed on a 5.25-in. (13.34-cm) 360K MS-DOS format diskette in PKZIP format with the PKUNZIP program. A personal computer is required to extract the files before moving the program to the CRAY computer. ZIP3D was developed in 1990.

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This program was written by James C. Newman, Jr., of **Langley Research Center** *and Kunigal N. Shivakumar of Analytical Services and Materials, Inc. LAR-14611/TN*

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NASA Tech Brief
National Aeronautics and Space Administration

Program Analyzes Crack-Growth Data

This program processes data from cyclic crack-growth tests.

The Crack Growth Rate Data Analysis computer program is used for cyclic crack-growth testing of compact tension specimens. The program facilitates the digitization of data on crack-opening displacement vs. load and the reduction of these data into data on crack-growth rate vs. stress-intensity excursion.

Key features of the program include (1) the extraction of data on crack-growth rates by use of the elastic-compliance method and (2) least-squares regression analysis of the data to determine constants for Collipriest, Paris, and modified Forman growth-rate equations. Data may be entered into the program from a keyboard or from a magnetic storage medium. Output is fed to a printer, plotter, and/or magnetic storage medium. The program also expedites editing of the crack-growth data and the combination of multiple data files.

The Crack Growth Rate Data Analysis computer program was developed in 1987 for use on the Space Shuttle program. The program is written in HP BASIC and runs on a HP9000 microcomputer. It also utilizes a Hewlett-Packard digitizer and plotter. This program is available only on 5-1/4 in. (13.3 cm) HP9000 SDF-format diskettes.

Hewlett-Packard, HP BASIC, and HP9000 are trademarks of Hewlett-Packard, Inc.

This program was written by Charles M. Demonet and James E. Collipriest of Rockwell International Corp. for **Johnson Space Center**. *For further information, Circle 123 on the TSP Request Card.*
MSC-21643/TN

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Medicine & Biology

0681 Heart Research

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0683 CEPH Provides Research Materials For Human Genetic Studies

0684 Periodontal Disease Activity Assessed

0685 Biomedical Technologies

Testing & Instrumentation

0686 Tester Replicates Severe Human-Body Electrostatic Shocks

Other Items of Interest

0620 Sound Reveals Salmonella

Department of Energy

Technology Application

Pittsburgh Energy Technology Center

Heart Research

Advanced diagnostic equipment developed by the Pittsburgh Energy Technology Center (PETC) researchers to study flow fields in coal utilization processes is now being applied to study hemodynamics of artificial heart pumps. The studies are being performed in PETC's Flow Analysis Laboratory by a team of researchers from PETC, Presbyterian-University Hospital, and two artificial heart pump companies. Under a CRADA with the University of Pittsburgh, the two heart pumps that will be studied are the Novacor LVAD and the Nimbus AxiPump.

One of the major problems facing patients with terminal heart disease is the availability of donor hearts for transplant. Each year an estimated 30,000 patients are in need of a transplant, but only about 2,000 acceptable donor hearts are made available. As a result, many patients who are candidates for transplant surgery do not survive until a donor heart becomes available.

The medical community is attempting to bridge the time gap between heart failure and cardiac transplant with the use of artificial heart pumps.

Today, emphasis is being directed toward using devices that assist an ailing heart instead of replacing it with a total artificial heart such as the Jarvik-7. One of these devices is a Left Ventricular Assist Device (LVAD) developed by Novacor, a division of Baxter Healthcare. The success rate with the Novacor LVAD is very encouraging--more than 70% of the Novacor LVAD implant patients at Presbyterian-University Hospital have been kept alive until a donor heart was found.

The shortage of donor organs and the requirement for a good "match" between donor and recipient is now significantly increasing the length of time an LVAD implant must be used. Over extended periods of contact between the patient's blood and the artificial surfaces within the LVAD, even subtle blood/device interactions may be of clinical importance.

The interactions between blood and artificial surfaces are a function of patient-dependent hematologic factors and the behavior of blood flow near the surfaces. Recent developments in laser-based flow imaging techniques at PETC have, for the first time, made possible detailed measurements of flow on surfaces within the Novacor LVAD. These developments allow the Flow Analysis Laboratory to assist the University of Pittsburgh and Novacor with the increasingly complex analysis of blood flow dynamics and its relationship to clinical LVAD management. This cooperative research contributes to the continuing effort to optimize device performance and the goal of improving the quality of life for cardiac transplant candidates.

Another implantable heart device being studied at PETC is the axial flow pump, developed by Nimbus, Inc., and known as the AxiPump. This is a revolutionary miniature LVAD consisting of a small turbine the size of a penlight battery. One of the many advantages of its small size is the reduced surface area in contact with blood. Another unique feature of the AxiPump is that, rather than being pulsatile like the human heart, it is a continuous flow device. An AxiPump patient with a very weak heart would have no significant pulse or systolic/diastolic blood pressure. According to Presbyterian-University Hospital medical researchers, this device could significantly reduce the demand for donor hearts and has the potential to save up to 30,000 lives per year.

For the AxiPump to work properly, the shear stresses imposed on blood must be kept within a narrow range. Excessive shear stresses can damage blood cells, while very low shear stresses tend to promote blood clotting. The flow velocities and resulting shear stresses in the AxiPump are being measured in the Flow Analysis Laboratory using high-speed photography and pulsed laser imaging techniques. This is a formidable task because flow fields must be measured across a millimeter gap between turbine blades that are spinning at 12,000 rpm.

For further information, contact Kay Downey, (412) 892-6029

Lawrence Berkeley Laboratory

New Gene Mapping Technique from LBL

A new method for locating the positions of genes on chromosomes has been developed by scientists with the Lawrence Berkeley Laboratory. Called "random-breakage mapping," the technique is a quick and relatively easy way of mapping internal DNA sequences with respect to the ends of a chromosome.

Mapping the location of the sequence of nucleotides that makes up a gene within the long stretch of DNA that makes up a chromosome has traditionally been a grueling and time-consuming process. For example, in the 50 years that scientists have been mapping the human genome, out of a total of some 100,000 genes, less than 2,000 have been located.

Random-breakage mapping could speed things up significantly. Developed by John Game, a biologist in LBL's Cell and Molecular Biology Division, working with Maren Bell and Robert Mortimer, and with Jeff King, of University of California at Berkeley's Department of Molecular and Cell Biology, this technique reveals the distance of a gene, or other specific sequence of DNA base-pairs, from the end of its chromosome. By comparing these distances for each gene within a given chromosome, the respective positions of those genes is easily determined.

"The technique is particularly useful when there is little information known other than which chromosome the DNA sequence is on," says Game. "Although it only works for sequences that are not repeated more than a few times, that should cover most of the genes people will want to map."

Random-breakage mapping is best understood by considering a chromosome that is broken only once. For a once-broken chromosome, the shortest fragment that can contain the DNA sequence of a specific gene must be a piece with the gene on the end.

"No fragment shorter than the distance from the sequence to the nearest end of the chromosome can contain that sequence without at least two breaks in the chromosome," says Game.

Game and his colleagues begin their technique by irradiating with low energy x-rays a sample containing a number of molecules of a specific type of chromosome. The irradiation is done at an intensity that will result in most of the molecules being broken only once at random locations. Propelling the fragments by an alternating electrical field through a gel - a technique known as gel electrophoresis - separates them according to size. Another standard technique called "Southern blotting" is then used to transfer the fragments onto a special paper that makes those containing a selected gene visible when the gene is hybridized with a radioactively labeled probe.

"The size distribution of these fragments is such that two threshold changes in the intensity of our probe signal are seen in the pattern formed below the unbroken chromosome molecules," says Game. "The positions of the changes represent the distances in base-pairs from the gene to the each end of the chromosome."

Game and his colleagues developed the random-breakage mapping technique for their research with yeast DNA. They verified the accuracy of their findings using four different yeast genes that had previously been mapped.

Random-breakage mapping cannot be used on whole human chromosomes at this time because even a once-broken human chromosome is still far too large to be resolved in today's electrophoresis gels. Even if a gel could resolve such large molecules, the probe signal might be too weak.

However, once a human gene known to be on a particular chromosome has been cloned, random-breakage mapping could be used to pinpoint its location. Restriction enzymes - enzymes that cut DNA at specific sites - would first be used to selectively fragment the chromosome. These restriction fragments, whose position along the chromosome is known, could then be handled in the same manner as yeast chromosomes in order to map the gene.

"I see no fundamental technical barriers to applying random-breakage mapping to the human genome," says Game. "Right now we are trying to map some probes on chromosome 21 to get around the problem of noise from too much DNA. Our preliminary results look good."

Game says the technique should also be well-suited to the analysis of mammalian DNA that has been introduced into yeast chromosomes (called YACs or yeast artificial chromosomes) for replication purposes, and to studies of DNA breakage and repair.

FOR ADDITIONAL INFORMATION: Public Information Department, ATTN: Lynn Yarris, Lawrence Berkeley Laboratory, Berkeley, CA 94720; Telephone (415)486-5375.

NIH
Research & Technology
U.S. Department of Health and Human Services Public Health Service National Institutes of Health

CEPH Provides Research Materials For Human Genetic Studies

Genetics researchers interested in mapping human genes soon will be able to obtain kits of cloned DNA probes from the Centre d'Etude du Polymorphisme Humain (CEPH), or Center for the Study of Human Polymorphism, in Paris, and from the American Type Culture Collection (ATCC) in Rockville, Maryland.

CEPH was established by Nobel Prize recipient Dr. Jean Dausset as a resource dedicated to helping investigators locate genes involved in genetic disorders. It recently was awarded a grant, in collaboration with the ATCC, to assemble and distribute chromosome-specific kits of DNA probes useful in genetic mapping. The ATCC also houses the NIH Repository of Mice and Human DNA Probes and Human Libraries. The CEPH/ATCC project is supported by the Biological Models and Materials Research Program of the NIH National Center for Research Resources.

"First, investigators at CEPH identified the particular clones that will be included in the kits," explains Dr. William C. Nierman, head of ATCC's department of molecular biology and coprincipal investigator on the CEPH project. "Some of these were already available in the ATCC repository. We went back to each of the contributors of the repository material for authorization to include it in the kits. For the clones that were not in our repository, we went to the investigators who had developed the clones and solicited the addition of these clones to the kits."

In addition to acquiring the probes for the kits, the ATCC prepares 1 mg of DNA and verifies the structure of each probe by restriction analysis. Samples are sent to depositors for review.

"The ATCC will send the probes to CEPH in Paris, where they will be labeled with radioisotope ^{32}P and further analyzed to verify that they do detect human polymorphisms—genetic variations—that are the keys to gene mapping. CEPH then will dispense the DNA into aliquots of 5 micrograms and make up the kits, half of which will be distributed by them and half by the ATCC," Dr. Nierman says.

The ATCC also will provide the information sheets included in each kit. These will be drawn from the database maintained on all the repository's materials, which contains information on more than 1,800 clones from the human genome. The sheets

William Siegel ATCC

Dr. William C. Nierman of the American Type Culture Collection is pipetting a sample of DNA used as a chromosome-specific probe in genetic mapping.

will include descriptions of polymorphisms the probe is useful for detecting, who developed the probe and provided it to the repository, and references to additional information available from the printed scientific literature and electronic databases.

The first kit to be produced, which is for chromosome 1, is available. Kits for chromosomes 4, 10, 21, and X will be available in mid-1992, Dr. Nierman says.

The investigators expect to create a kit for each of the 22 paired chromosomes and the X and Y sex chromosomes, with each kit containing 10 to 20 markers. Although they cannot estimate how many kits will be requested by researchers, the grant allows production of 200 kits for each chromosome.

Dr. Nierman explains how the chromosome studies are done: "We have, for example, the kit for chromosome 1, which contains 17 markers that are in known locations spread across the entire chromosome. An investigator who is interested in mapping a specific gene and who knows this gene is on chromosome 1 can use the kit to position the gene relative to these markers."

The ATCC will charge a nominal fee for the kits it distributes. The cost will vary; some kits contain more material than others and accordingly will cost more, he notes.

Another service the ATCC provides for researchers is direct, free telephone access to a user-interactive database of all the probes and primer sequences in the kits. The user must be able to emulate a VT100 terminal (8 data bits, 1 stop bit, no parity, full duplex) to enter the database. Logon is automatic after calling 1-800-647-4710, typing [enter], and answering the username and password prompts with the word "common" followed by [enter]. Local callers can use (301) 881-4909.

For further information on CEPH, contact:
Dr. William C. Nierman
Head, Department of Molecular Biology
American Type Culture Collection
12301 Parklawn Drive
Rockville, MD 20852
(301) 231-5559

For Additional Information:

To locate information or professional contacts on this effort, contact:

Research Resources Information Center
1601 Research Boulevard
Rockville, MD 20850
(301) 251-4970

Refer to Volume XVI, No. 1/TN

Periodontal Disease Activity Assessed

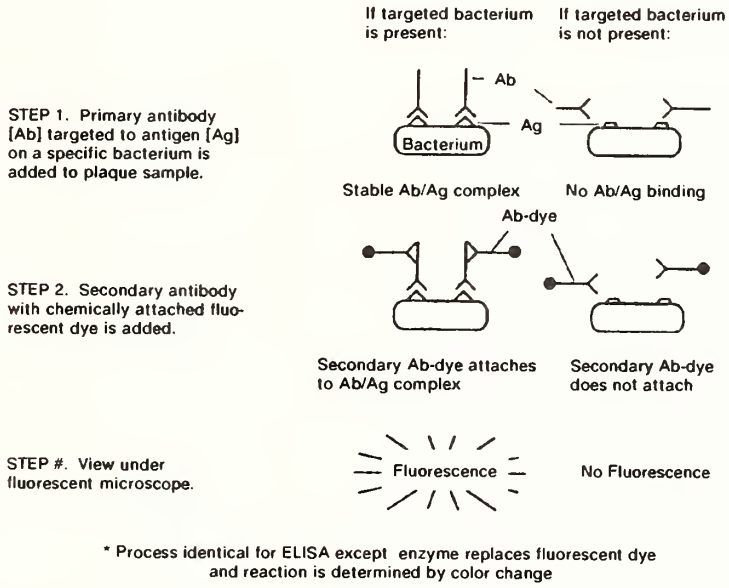

If targeted bacterium is present:
If targeted bacterium is not present:
STEP 1. Primary antibody [Ab] targeted to antigen [Ag] on a specific bacterium is added to plaque sample.
Ab
Ag
Bacterium
Stable Ab/Ag complex
No Ab/Ag binding
Ab-dye
STEP 2. Secondary antibody with chemically attached fluorescent dye is added.
Secondary Ab-dye attaches to Ab/Ag complex
Secondary Ab-dye does not attach
STEP #. View under fluorescent microscope.
Fluorescence
No Fluorescence
* Process identical for ELISA except enzyme replaces fluorescent dye and reaction is determined by color change

Figure 3. Immunofluorescence microscopy

Based on the premise that specific organisms are related to various forms of periodontal disease, the Naval Dental Research Institute Great Lakes, Illinois, has developed methods to detect specific bateria in subgingival plaque. These tests unlike traditional clinical evaluation methods, such as probing depths and attachment level, may enable the therapist to assess the present status of disease activity and may be able to predict or detect actively progressing disease. These microbiological tests include, but are not limited to, immunofluorescence microscopy (Figure 3), ELISA, latex agglutination, and DNA probes. Currently, most of the microbiological methods involve the use of laboratory facilities for analysis. However, the development of simplified chairside diagnostic kits for the dental office is anticipated in the near future.

For Additional Information:

Backup material on this effort is available from:

Navy Domestic Technology Fact Sheet Reader Reply Service
Code E211
Naval Surface Weapons Center
Dahlgren, VA 22448-5000
(703) 663-8921

Refer to 170104/TN

HHS Fact Sheet

U.S. Department of Health & Human Services

Biomedical Technologies

The following are summaries of two pharmaceutical agent technologies developed by the Centers for Disease Control that are available for licensing.

Immortal human endothelial cell line

Endothelial cells are critical components of wound healing, inflammation, circulation, and tumor growth metastases. Endothelial cells are difficult to isolate and culture. A unique approach has been used to immortalize endothelial cells which will be of great value to a large number of scientists throughout the world. The cell line is quite easy to culture.

The cell lines provide a ready source of human endothelial cells for research purposes. Examples include studies on the physiologic and pathologic factors that induce endothelial mitosis; pharmacological studies as substrates for the screening of various agents, and toxicity studies for the cosmetic and pharmaceutical industry. These cell lines also produce factors which are released into serum-free medium.

A U.S. Patent Application has been filed and the technology is available for non-exclusive license or exclusive licenses for specific fields of use.

Raccoon Poxvirus as Geno Expression and Vaccinia Vector for Genes of Rabies Virus and Other Organisms

An oral rabies recombinant vaccine, based on a putative indigenous raccoon poxvirus, has been developed using raccoon poxvirus as the expression vector. The vaccine confers protection against rabies to a number of wild and domestic animals. Because humans are not a natural host for raccoon poxvirus, other veterinary vaccines have been produced using this system as the expression vector.

A U.S. Patent is pending. Field of use exclusive license is available for vaccine products.

For more information, contact Frances Reid-Sanden, (404) 639-3812.

Department of Energy

Technology Application

Sandia National Laboratory

Tester Replicates Severe Human-Body Electrostatic Shocks

A simulator that mimics the severe static electric discharge that can be triggered by a human body has been developed at Sandia National Laboratories.

The simulator, called the Severe Human Body Electrostatic Discharge Tester (SSET), was designed to test semiconductors, explosive devices, and electronic systems, which can malfunction or be destroyed if subjected to such a shock.

Static electricity is an accumulation of charge on an insulated object. It can be produced when a person walks across a carpeted floor, gets out of a car, or stands outdoors in the wind. When accumulated charge is suddenly transferred to another object or person, either through direct contact or a spark, it is called electrostatic discharge (ESD).

The ESD from a person or object is a potential threat to semiconductors, explosives, and electronic systems. It can temporarily interfere with the operation of systems or components or cause permanent damage, possibly impairing their reliability and safe operation.

"At Sandia, we're concerned about what happens in the severe case," says John Barnum. "We have to be worried about those low-probability events."

Billion-dollar annual problem

The effects of ESD can generate significant losses in terms of life, property, and dollars. For example, in the electronics industry, losses associated with ESD are estimated at between a half billion and five billion dollars annually. The unintentional detonation of explosives (fireworks, industrial explosives) can cause significant loss of life and property damage.

With the costs so high, Sandia researchers have devoted considerable attention to assessing the vulnerability of components and systems to the ESD threat. To do that, experimental tests are performed by applying a known, simulated discharge that mimics the actual event as closely as possible. When a high degree of reliability or safety is needed, a "severe" ESD simulation is used. The simulator developed at Sandia was designed to simulate a severe environment and can replicate a human body ESD up to 35 kV.

When human beings acquire charge, the potential difference between the body and the ground will normally rise to between 6 and 12 kilovolts (kV). However, under dry conditions (10 to 20 percent relative humidity), a person can develop and sustain voltages of about 35 kV or slightly greater. Normally, it is difficult to achieve and sustain voltages of greater than 25 kV due to the "corona" effect in which some of the accumulated charge spontaneously disperses, lowering the voltage.

Sandia researchers have also investigated factors influencing ESD effects such as maximum sustainable voltages, humidity, individual height, etc. They have assembled a data base from scientific literature of documented measurements of human body electrical parameters (voltage, capacitance, resistance and inductance) that have been developed into an electrical model of the human body.

The model, developed by Sandian Dick Fisher, uses the extremes of the documented data to define a severe human body ESD model that is intended for use in qualification testing of systems with stringent safety and/or reliability requirements. The model exhibits the distinctive characteristics of an actual human body ESD waveform, having an extremely fast rise time to peak current (approximately one nanosecond), and an initial voltage of 25 kV. It also specifies that current be injected directly into a test object without a spark, which replicates the most severe stress created by an ESD.

The model was used to develop the SSET. Although a wide variety of ESD simulators exist commercially, none could adequately address all the requirements identified in the severe human body model.

The SSET is constructed of off-the-shelf and easily fabricated components and costs approximately $750 in parts, excluding the power supply.

Although the SSET is intended primarily to simulate a severe human body ESD event, the flexibility of the design allows for other ESD sources to be simulated.

Sandia researchers are currently using the SSET and other types of pulse sources to investigate the effects of human body and other forms of ESD on electronics and explosives.

FOR ADDITIONAL INFORMATION: Technical Contact: John Barnum (505) 844-4367, Department of Energy, Sandia National Laboratories, Albuquerque, NM 87185-5800.

Natural Resources Technology & Engineering

0687 Another Technique for Calibration of Polarimetric Radar—The only artificial target(s) required is at least one trihedral corner reflector.

0688 AVIRIS Spectrometer Maps Total Water Vapor Column—Column abundances are mapped with good precision and spatial resolution.

0689 Condensed Acids in Antarctic Stratospheric clouds—Amounts of nitric, sulfuric, and hydrochloric acids are probably related to the depletion of ozone.

0690 Monitoring Global Temperatures From Satellites—Microwave radiometers measure temperatures with useful precision. (Licensing Opportunity)

0691 N2O as a Tracer of Antarctic Atmospheric Flows—Experimental data are relevant to studies of the depletion of ozone.

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Another Technique for Calibration of Polarimetric Radar

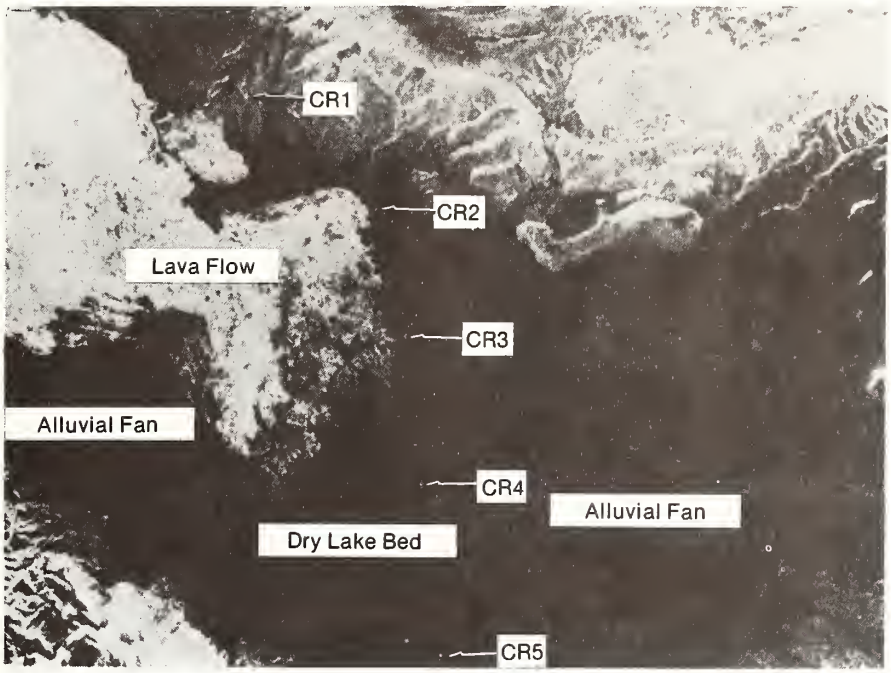
The only artificial target(s) required is at least one trihedral corner reflector.

A technique for the calibration of a polarimetric radar system requires a minimum of only one artificial target in the scene, or if only the crosstalk of the system is to be calibrated, no artificial target is needed. This is the latest in a series of polarimetric-radar-calibration techniques developed by NASA's Jet Propulsion Laboratory and reported in *NASA Tech Briefs*. This is a relatively inexpensive technique that involves a four-stage procedure in which a different aspect of the radar system is calibrated at each stage.

The technique applies to polarimetric synthetic-aperture-radar data that have been preprocessed into a compressed form. As part of the preprocessing, the measured scattering matrix for each resolution element is symmetrized. This symmetrization is equivalent to an assumption that the transmitting and receiving subsystems are reciprocal. The assumption, in turn, is only approximately true, and one of its consequences is that the estimated parameters of the system may not have any simple relationship with the parameters of the real transmitting and receiving equipment. Nevertheless, the data can still be calibrated by use of the estimated parameters of the system, so that the true Stokes matrix for each resolution element can be determined.

The technique provides for calibration of relative phase, crosstalk, relative amplitude, and absolute amplitude. The relative-phase calibration is performed in the first stage of the calibration procedure by use of a phase-equalization scheme that has come into routine use in recent years. This scheme does not require any artificial calibration targets in the scene but does depend on the existence of a portion of the scene for which the difference between the phases in the two copolarization (horizontal/horizontal and vertical/vertical) backscattering channels are known.

The crosstalk calibration is performed in the second stage of the procedure. This calibration also does not require any artificial calibration targets in the scene. It is based on the assumption that (1) the crosstalk is relatively small and (2) the copolarization and cross-polarization components of the scattering matrices of natural targets distributed over the scene are uncorrelated. The crosstalk parameters are extracted from statistics of various cross products of (1) scattering matrices based on the preprocessed but otherwise raw radar-return data and (2) intermediate scattering matrices that lack only relative-amplitude and radiometric calibrations.



This is a C-Band Radar Image of the Pisgah lava flow in the Mojave Desert. To calibrate the radar data, five corner reflectors were placed in the scene at the locations marked CR1 through CR5.

The calibration for relative amplitude (between the two copolarization channels) is performed in the third stage. It requires trihedral corner reflectors in the scene (see figure). The result is a radar image in which all the radar channels are calibrated with respect to each other in amplitude and phase. In the fourth stage, an overall absolute radiometric calibration is performed by comparison of the measured with the known radar cross section of trihedral corner reflectors in the scene. (Other artificial targets could be used, but trihedral corner reflectors are cheap and relatively insensitive to misalignments.)

One of the advantages of the four-step calibration procedure is that one does not have to perform the entire procedure if one does not need the full calibration. For example, if all that is needed is a calibration for crosstalk, it is not necessary to continue past the second stage of the procedure.

This work was done by Jakob J. van Zyl of Caltech for **NASA's Jet Propulsion Laboratory**. *NPO-18068/TN*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

AVIRIS Spectrometer Maps Total Water Vapor Column

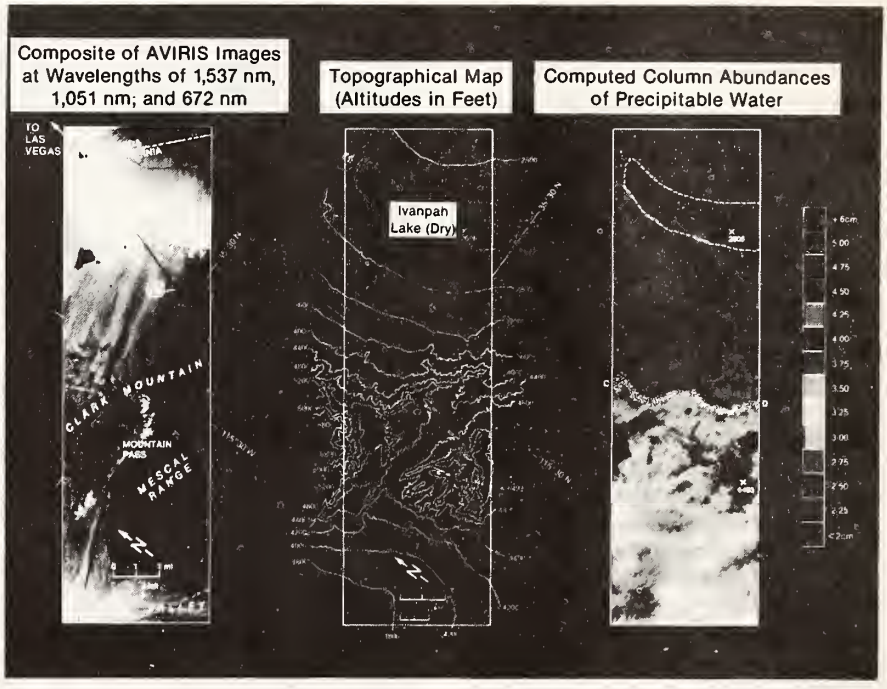
Column abundances are mapped with good precision and spatial resolution.

Observations by NASA's Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) have been processed into maps of vertical-column abundances of water vapor in the atmosphere. Such maps can provide valuable information for meteorology, climatology, and agriculture.

AVIRIS takes near-nadir measurements of spectral radiance in spectral sampling intervals 10 nanometers wide at wavelengths from 400 to 2,500 nm. Mounted in a U-2 airplane flying at an altitude of 20 km, AVIRIS scans a swath 11 km wide with an instantaneous field of view of 20 m by 20 m at the surface. In this case, spectral radiances are measured in two wavelength bands: a continuum band at 870 nm and a water band at 940 nm. According to a mathematical model developed for this purpose, the ratio between these two radiances is a function of the total column abundance of precipitable water as measured through (1) the path of downwelling solar radiation and (2) the path of upwelling radiation reflected from the surface up along the observed path to the spectrometer.

The AVIRIS measurements are calibrated with the help of surface measurements of bidirectional reflectances of selected targets in the scene. Corrections for the altitude of the surface, the viewing angle, and flight conditions are made. The use of the ratio of radiances helps to compensate for variations in albedo (bright and dark areas) over the surface: this is because the two spectral bands are close and, consequently, the differences between the spectral reflectances in the two bands should be small.

The figure illustrates the results obtained by applying this method to a desert area in eastern California. An independent validation of the column abundance at one location derived from the AVIRIS data was supplied by a spectral hygrometer calibrated with respect to radiosonde observations. The column abundances of water vapor were found to conform to topography and to decrease with surface elevation. Overall, the ratio method was found to yield column abundances of good precision and high spatial resolution.


Composite of AVIRIS Images at Wavelengths of 1,537 nm, 1,051 nm; and 672 nm
Topographical Map (Altitudes in Feet)
Computed Column Abundances of Precipitable Water
TO LAS VEGAS
CLARK MOUNTAIN
MOUNTAIN PASS
MESCAL RANGE
Ivanpah Lake (Dry)

Column Abundances of Water Vapor estimated by the ratio method described in the text are compared with a composite three-wavelength image and a topographical map. The stippled region CD denotes a sharp change in column abundance that may represent the edge of the water-vapor boundary layer tapered against the topography. A denotes a location where optical depth was determined; B denotes a playa used as a calibration target.

This work was done by James E. Conel, Robert O. Green, Veronique Carrere, Jack S. Margolis, Ronald E. Alley, Gregg A. Vane, Carol J. Bruegge, and Bruce L. Gary of Caltech for **NASA's Jet Propulsion Laboratory.**
NPO-18023/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and
Space Administration

Condensed Acids in Antarctic Stratospheric Clouds

Amounts of nitric, sulfuric, and hydrochloric acids are probably related to the depletion of ozone.

A report discusses measurements of the nitrate, sulfate, and chloride contents of stratospheric aerosols during the 1987 Airborne Antarctic Ozone Experiment. Data from these measurements are important in testing theories concerning the Antarctic "ozone hole." This study emphasizes data concerning the growth of $HNO_3 \cdot 3H_2O$ particles in polar stratospheric clouds, in the context of these theories.

Aerosols were sampled by an airplane flying between 57° and 72° south latitude at an altitude of 18 km. The aerosol particles were collected by impact on four 500-μm-diameter gold wires strung across aluminum rings. The wires were pretreated to give results specific to certain physical and chemical properties of the aerosols. One wire was coated with carbon and used for analyses, via scanning electron microscopy, of the sizes and concentrations of aerosol particles. One wire was coated with nitron [$CN_4(C_6H_5)_3CH$], which undergoes reactions that indicate the presence of nitrates. The other two wires were coated with barium chloride and silver nitrate to detect sulfuric and hydrochloric acids, respectively. Immediately after collection and while the flights continued, the acids were fixed as ammonium salts by exposing them to ammonia.

The results show that condensed nitric acid is found at temperatures below a threshold of 193.6 ± 3.0 K, generally encountered at south latitudes above 64° at the 18-km altitude. Consistent with theories of the condensation of $HNO_3 \cdot 3H_2O$, particles of nitric acid were not detected at temperatures above 200 K. Below the threshold temperature, the concentrations of nitric acid particles and of ozone were negatively correlated with each other, with a correlation coefficient of −0.7. This is consistent with theories in which the freezing-out of nitrates is a prerequisite for reactions of gaseous chlorine compounds with ozone.

The collected sulfates indicated the presence of liquid sulfuric acid aerosol particles in concentrations that ranged from 0.06 to 0.11 $\mu g/m^3$. Such concentrations are comparable to those found in northern midlatitude aerosols in the absence of volcanic activity. Hydrochloric acid was found to be present, but in only a few cases was the concentration great enough to be measurable by energy-dispersive x-ray analysis. From the limited available data, it was estimated that the mass of HCl in the specimens was about 4 percent of the mass of H_2SO_4.

This work was done by R.F. Pueschel, K.G. Snetsinger, O.B. Toon, G.V. Ferry, W.L. Starr, V.R. Oberbeck, and K.R. Chan of **Ames Research Center**, *J.K. Goodman of San Jose State University, J.M. Livingston of SRI International, S. Verma of TMA/Norcal, and W. Fong of Information Management Inc. "Condensed Nitrate, Sulfate, and Chloride in Antarctic Stratospheric Aerosols."*
ARC-12618/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration

Licensing Opportunity

Monitoring Global Temperatures From Satellites

Microwave radiometers measure temperatures with useful precision.

A report published in the 30 March 1990 issue of *Science* provides evidence that passive microwave radiometry from satellites provides more-precise information on atmospheric temperatures than does the relatively sparse distribution of thermometers over the surface of the Earth. Accurate estimates of global atmospheric temperatures are needed for detection of possible "greenhouse" warming, for evaluation of computer models of change in climate, and for understanding important factors in the climate system.

The authors examined data from microwave sounding units (MSU's) carried aboard the TIROS-N series satellites of the National Oceanic and Atmospheric Administration (NOAA). The MSU's are Dicke-type radiometers designed to measure the thermal emission of radiation by atmospheric O_2 at four frequencies near 60 GHz. The authors examined, in particular, data from MSU channel 2 (53.74 GHz), which measures the temperature of the middle troposphere.

Each MSU is calibrated externally by measurement of the cosmic background radiation, which is assumed constant at a temperature of 2.7 K. It is also calibrated internally by a warm target, the temperature of which is monitored by redundant platinum resistance thermometers. This calibration procedure cancels the effects of changes in the components of the MSU. Each Earth-viewing measurement is then calculated as a "brightness temperature" (T_b) by interpolation between the two calibration temperatures. Because the tropospheric O_2 closely approximates a blackbody in MSU channel 2, its thermometric temperature (the temperature that would be indicated by a thermometer in contact) is closely approximated by T_b.

Comparison of T_b data from channel 2 (averaged at 2-day intervals over both the Northern and Southern Hemispheres) from two satellites operating simultaneously during the period from 29 June 1981 to 16 April 1983 in Sun-synchronous, near-polar orbits revealed the following:

- The standard deviation of the sums of the data from the two satellites is much larger than the standard deviation of the differences between the data. This means that both satellites were measuring nearly the same variations in temperature and implies that hemispheric temperature anomalies can be measured with relatively little error from a single satellite. The 2-day average difference between temperatures measured by the two satellites was about 0.05 °C; the monthly average difference was about 0.011 °C. The authors estimate that the precision of monthly satellite measurements is about ±0.01 °C for the globe.
- The sums of the two sets of data reveal that dramatic globally averaged warming and cooling events of greater than 0.5 °C can occur in less than 2 weeks. The warmings are possibly associated with stormy periods, when large amounts of latent heat were released in precipitation of moisture previously evaporated from the Sun-warmed ocean. The coolings might be associated with the formation of widespread low-level cloudiness, which reflects significant amounts of incoming solar radiation.
- The long-term drift of one MSU relative to the other is so small (<0.01 °C in 2 years) that it is virtually unmeasurable.

To demonstrate that MSU measurements are closely related to thermometric temperature, the authors compared monthly temperature anomalies from thermometers over the contiguous United States for the period 1979 through 1987 to the monthly midtropospheric temperature anomalies measured from the satellites. (The distribution of thermometers over the United States is widely accepted as good enough for climate work.) The resulting anomaly time series were similar, as verified by a scatter plot and a correlation coefficient of 0.89. This correlation agrees with those between radiosonde near-surface and upper-air measurements.

Satellite data for the years 1979 to 1988 reveal large fluctuations in the hemispheric and global temperatures. The slower, interannual trends in the Northern and Southern Hemispheres follow each other, but on monthly-to-seasonal time scales; the trends in the two hemispheres often oppose each other. The warmest years during the experiment, in decreasing order of temperature, were 1988, 1987, 1983, and 1980; the years 1984, 1985, and 1986 were the coolest. There is no obvious long-term trend, and anomalies during the first 5 years nearly balance those during the last 5 years. The 10-year time series exhibits bifurcation in that there are 9 cool or warm years and only 1 year (1981) that could be considered "average." This pattern makes the definition of "normal" for global temperatures uncertain.

This work was done by Roy W. Spencer and John R. Christy of **Marshall Space Flight Center**. *"Precise Monitoring of Global Temperature Trends From Satellites."*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center. Refer to MFS-27248/TN.

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NASA Tech Brief
National Aeronautics and
Space Administration

N_2O as a Tracer of Antarctic Atmospheric Flows

Experimental data are relevant to studies of the depletion of ozone.

A report discusses the use of natural N_2O as a tracer gas in the effort to determine large-scale lower stratospheric air flows during the 1987 Airborne Antarctic Ozone Experiment. Data on such flows are essential to understanding the vertical motions and the horizontal transport of air into and out of the southern polar vortex and the "ozone hole," and as such can be used to test theories on the depletion of ozone. N_2O was chosen as a tracer because (1) it has purely tropospheric sources, (2) it has a tropospheric lifetime > 20 years and is therefore well mixed (with a geographic variation of less than 1 percent) throughout the troposphere, and (3) it has a long chemical lifetime in the lower stratosphere (altitudes of 12 to 20 km), where the Antarctic ozone is being lost.

Concentrations of N_2O were measured by an airborne second-harmonic absorption spectrometer containing a $Pb_{1-x}Sn_xTe$ tunable diode laser that operated near the ~1,300 cm^{-1} absorption line of N_2O. These measurements have a temporal resolution of 1 s, which, at the speed of the ER-2 airplane, yields a spatial resolution of ~200 m. Pressures, temperatures, and latitudes were also recorded by a meteorological measurement system.

Data were taken on 12 flights into the Antarctic vortex (which is bounded approximately by the circle at 60° south latitude) and on 5 flights outside the vortex during August and September of 1987. Vertical distributions of N_2O were obtained within the vortex on most of these flights, and outside the vortex on some of them. Altogether, the measurements yielded an extensive new set of data on the concentration of N_2O in the lower stratosphere at latitudes from 41° S to 72° S during the late Antarctic winter and early Antarctic spring.

Instead of altitude, the "natural" vertical coordinate used to present the data on N_2O is the potential temperature, θ, which is based on an isentropic model of the variation of pressure, temperature, and density with altitude. For a given parcel of air moving in the lower stratosphere, θ tends to be conserved for several days, N_2O and θ are transported together by atmospheric motions, and mixing tends to equalize the concentrations of N_2O on surfaces of constant θ.

The data from flights into the vortex show that the concentration of N_2O decreased from 53° to 72° south latitude on surfaces of constant θ in the lower stratosphere. The data lead to two important conclusions: (1) The lower stratosphere at that time was occupied by "old" air, which had subsided several kilometers during the Antarctic winter; and (2) the distribution of N_2O in the vortex was approximately in a steady state at that time, indicating that the spring upwelling of air, suggested by several theories, did not occur.

This work was done by M. Loewenstein, J.R. Podolske, and K.R. Chan of **Ames Research Center** *and S.E. Strahan of the National Research Council. "Nitrous Oxide as a Dynamical Tracer in the 1987 Airborne Antarctic Ozone Experiment."* *ARC-12453/TN*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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Physical Sciences

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Sandia National Laboratory

Chemometrics Uses AI Pattern-Recognition Techniques

Sandia National Laboratories scientists are exploring and developing chemometrics, a new branch of analytical chemistry, using techniques that are related to the pattern recognition techniques used in artificial intelligence.

Chemometrics allows researchers to sift through vast quantities of data systematically to extract useful quantitative information. While it can be applied to a wide range of chemical data, Sandia researchers have adapted it to analyze information acquired through spectral measurements. Such measurements are rapid, nondestructive, don't require chemical separations, and are easily automated.

Chemometric methods being applied at Sandia are based on computer-aided analysis of the colors that are characteristically absorbed or emitted by certain materials—a technique called spectral analysis because it refers to the absorption or emission of light in the electromagnetic spectrum.

The technique is used to design experiments and to obtain useful information about unknown samples of material. This information typically might be identification of the chemical components (molecules or atoms) present in the sample, and the quantity of each component identified.

Software works on personal computers

David M. Haaland of Sandia and David K. Melgaard, a J&M Systems scientist working under contract to Sandia, recently were awarded an SRC/SEMATECH Inventor Recognition Award for developing chemometrics software for use on personal computers. SRC, Semiconductor Research Corporation, manages SEMATECH's Centers of Excellence.

The original software, as developed by Haaland and Melgaard with Edward V. Thomas of Sandia's Statistics, Computing, and Human Factors Division, was available only for use on VAX systems. This was converted to a PC-compatible format so that the technology would be more universally available to U.S. industry. Melgaard wrote the PC chemometrics program from Haaland's specifications.

Sandia's contributions to chemometrics consist of developing, improving, and applying "multivariate" calibration and prediction methods—making use of spectral data acquired at all wavelengths of interest.

Multivariate analysis uses techniques that are a superset of some of the pattern recognition techniques used in artificial intelligence applications. First, an analyst prepares a series of samples having known compositions and then records their spectra. Next, the analyst "trains" a computer program to recognize the spectral characteristics of those samples. Last, the analyst supplies the computer program with spectral data from an unknown sample and asks the program to quantitatively analyze the data for composition. If the composition of the unknown sample is within the range over which the program was trained, the program will provide reliable, quantitative results. Otherwise, when the composition or spectrum is outside the calibration range, statistical indicators will clearly show that the results are invalid.

More precision, accuracy, reliability

Multivariate methods offer analysts several advantages over previous techniques. These include greater precision, higher accuracy, increased reliability, improved identification of suspicious data, the ability to address a new range of problems, and the capability to relate spectra empirically to the chemical and physical properties of the sample.

"The predictive techniques employed in chemometrics greatly reduce the ever-present concern among experimental scientists about data validity," says Haaland, a staff member in Sandia's Chemical Instrumentation Research Division. "The methodology allows analysts to detect and reject 'outliers,' which are samples whose spectra lie outside the data range of the calibrated samples. This situation can arise when the unknown sample differs in subtle ways from the calibration sample."

A particularly powerful capability of multivariate analysis is that it allows analysts to construct empirical models to predict an unknown sample's chemical and physical properties from its spectra.

"Chemometrics represents a powerful new set of analytical tools for chemists," says Laura Gilliom, supervisor of Sandia's Chemical Instrumentation Research Division. "The methodology will undoubtedly gain wider acceptance as chemists become aware of its capabilities, and as research organizations like Sandia improve upon the state of the art.

"The software includes unpublished Sandia-developed outlier detection methods used to improve the reliability of the analyses. SRC and SEMATECH

are interested in the software because it can be used in process monitoring and at-line and in-situ analyses of thin-film dielectrics used in the manufacture of integrated circuits. It is also being investigated for use in monitoring plasmas during plasma etching."

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Sandia National Laboratory

Interfacial Force Microscope Probes Atomic-Level Forces

A unique sensor that can measure the forces that develop between two surfaces as they approach each other at the atomic level and come into contact has been developed at Sandia National Laboratories.

The researchers say it is the first sensor that can measure interfacial forces over the entire range of separation at the atomic scale.

Sandia scientists want to know how solid surfaces stick together - what forces bind the interface. The new sensor, called the interfacial force sensor, is a key part of a new Sandia program supported by the Basic Energy Sciences division of the Department of Energy to achieve a fundamental understanding of this matter. Why materials stick and why they come apart is a crucial issue in many aspects of engineering and design.

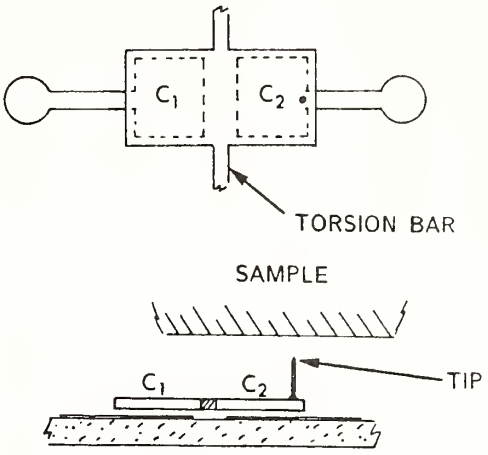
They want to learn how surface modification can be controlled to either increase or decrease the binding energy between solid surfaces and thus understand and control the process of adhesion. The sensor is already providing some new scientific insights into these interactions.

Adhesion is usually studied by forming an adhesive bond and then trying to pull it apart. This is the first attempt to study the binding between materials by watching the adhesive bond form as one brings the materials into contact.

In addition to the adhesive process itself, other important phenomena such as fracture, friction, wear, lubrication, and the role of corrosion in attacking the adhesive bond can also be studied at a fundamental level using this new technique.

The sensor also has practical applications in detecting defects on microelectronics circuitry and in studying how these defects affect adhesion.

The interfacial force sensor combines aspects of atomic force microscopy (AFM) and scanning tunnelling microscopy (STM). Both these techniques involve scanning a sharp probe tip at atomic distances above a sample. (The researchers at IBM Zurich who developed the STM, which provides topographic images of atomic surfaces, received the 1986 Nobel Prize in physics.)



Sandia interfacial force microscope uses a unique differential-capacitance force sensor with a field-emitter "tip" on one end. Tip forces imbalance the capacitance and are detected by an RF bridge. System is rebalanced by applying voltage to the appropriate capacitor, thus avoiding "snapping" problems.

When combined with existing imaging technology and mounted on a three-axis piezoelectric drive, such as used with STM, the new Sandia sensor lends itself to raster scanning to make an interfacial force microscope (IFM). The scientists say such a microscope will be able to form three-dimensional images for the full range of interfacial forces - both attractive and repulsive.

The forces that bind surfaces together arise from a variety of physical and chemical phenomena. As an example, a thin liquid layer can result in capillary forces, while electrically charged species on the surface can contribute to long-range electrostatic attractions. By measuring the entire force profile, up to contact, Sandia scientists can determine the nature of the adhesive interaction.

The new sensor has a sharp tip not unlike that used in a scanning tunneling microscope. The tip (comprising one of the two surfaces being studied) is brought into proximity with a flat surface in order to study the interracial forces that develop.

The interfacial force microscope is centered around the

sensor - a differential-capacitance detector consisting of a capacitor plate supported by torsion bars like a teeter-totter. The tip is affixed to one end of this teeter-totter.

What is unique is that the sensor incorporates an electronic force-feedback control system that maintains the capacitor plate at its rest position.

Conventional sensors, in contrast, use cantilever-based sensors that gradually deflect in response to the attractive force but then suddenly "jump" or "snap" together as the rate of change of the attractive force exceeds the mechanical stiffness of the cantilever. The same jump-to-contact effect is observed if one tries carefully to bring two kitchen magnets together. At some small separation, the magnetic attraction can't be resisted and the magnets slap together. This jumping instability makes it impossible to measure the interfacial forces at separations any closer than where the snap occurs.

By using force feedback control, the Sandia sensor avoids the snapping problem altogether. The capacitor can not only detect a force (the attractive or repulsive force between two surfaces coming into proximity), it can exert a force. The sensor's feedback loop automatically applies an electrical potential that creates a counter force. The interfacial forces are read out by the amount of force the detector has to exert to compensate for them.

"The capacitor acts both as the displacement detector, through changes in capacitance, and as the counterbalance by the application of electrostatic restoring forces," says Sandia researcher Jack E. Houston, developer of the sensor in Sandia's Surface Science Division.

The capacitor thus stays in a fixed position and doesn't snap, all the time providing a continuous measurement of the interfacial force as the sensor tip and a flat surface come together.

In this way the entire range of interfacial forces can be probed in one experiment. A complete profile of force versus separation distance can be obtained.

"This new capability for measuring interfacial forces will allow us to uncover the detailed mechanisms of adhesion and interfacial bonding," says Terry A. Michalske, supervisor of Sandia's Surface Science Division and head of the new program to study interfacial forces.

In addition to studying fundamental properties of adhesion, the interfacial force sensor can be used as a microscope to look at features on a surface. This may be useful in such fields as microelectronics. Because a scanning tunneling microscope requires a current to flow between tip and sample, it works on metals but not on insulators. An IFM does not have that limitation. Houston says an AT&T Bell Laboratories group is already using the Sandia concept to look for microscopic defects in the lithographic masks used in integrated circuits.

The present sensor can detect interfacial forces as small as one-millionth of a newton, which is about the force required to pull two neighboring atoms apart. The sensor can detect changes in interfacial separation of about 0.5 nanometer (one half of one billionth of a meter), which is about the diameter of an atom of sodium.

In the first application of the IFM, Sandia scientists have collaborated with Professor Richard Crooks and graduate student Ross Thomas from the Department of Chemistry at the University of New Mexico. They have studied the adhesive behavior between a tungsten tip, only a few hundred atoms in diameter, interacting with a gold surface when the surface is covered with a single layer of a particular organic molecule - a normal alkane thiol - used as a lubricant. This molecule consists of a 16-carbon-atom hydrocarbon chain terminated on one end by a sulphur atom and on the other by three hydrogen atoms, called a methyl group. The sulphur atom interacts strongly with the gold surface, and the hydrocarbon chains stand virtually erect in an ordered monolayer like equally spaced stalks of wheat.

The scientists don't see any attractive interaction to the methyl terminal groups, but they have found that when the molecules are crunched down - like stepping on wheat - they recover after only a second or so. This is the first such time measurement of this monolayer "self assembly" process.

They have also found that the normally strong plastic interaction between tungsten and gold - an unwanted "galling" interaction when the two metals are in contact - is completely passivated by the organic layer. Even if the layer is pushed down, no attractive interaction is seen. This is an important insight into understanding the unique lubricating effect of the organic layer.

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NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

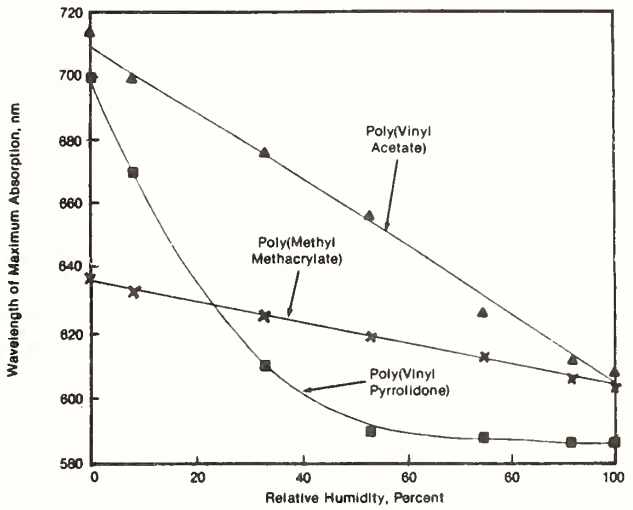
Colorimetric Detection of Substances in Liquids and Gases

The colors of solvatochromic dyes dispersed in thin films change upon exposure.

Thin polymer films containing solvatochromic dyes are used as sensing elements in a new method for the colorimetric detection of substances dissolved in liquids and gases. Solvatochromic dyes have been known for years as dyes that do not react chemically with liquids in which they are dissolved but do respond to changes in the chemical compositions of the liquids by changing in color.

In the new method, a dye that responds to the substance(s) that one seeks to detect is incorporated in a film of polymer that is pervious to the substance(s). The film is exposed to the gas or liquid that contains the substance(s), and its color changes rapidly. The concentration of the substance(s) in the liquid or gas is determined either visually by comparison of the color of the film with a predetermined standard color chart or spectrophotometrically; e.g., by measurement of the wavelength of maximum absorbance.

The method admits of useful variations. For example, another film that is pervious to only certain specified substances can be placed on the sensing film so that only those substances are allowed to reach the dye and produce detectable changes in color. One could also combine this approach with measurement of the change of the absorption spectrum with time to determine the permeability of the covering film to the specified substances.



The **Wavelength of Maximum Absorption of Light** in three polymer films that contained a solvato-chromic dye was measured as a function of relative humidity.

Experimental sensing films to measure humidity were made of three polymers containing the solvatochromic dye 2,6-diphenyl-4-(2,4,6-triphenyl-N-pyridinio)phenolate, which is sensitive to water molecules. The wavelength of maximum absorption in the ultraviolet and visible spectrum of these films was found to decrease with relative humidity. The best results (in the sense of the steepest and most nearly linear dependence on humidity) were obtained with poly(vinyl acetate) (see figure). The time required to attain the equilibrium value of the wavelength of maximum absorption depends on the thickness of the film and the rate of flow of air across the film; poly(vinyl acetate) films 10 μm thick were found to give equilibrium values within 10 to 15 s.

This work was done by J. Milton Harris, R. Andrew McGill, and Mark S. Paley of the University of Alabama in Huntsville for **Marshall Space Flight Center.**

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center. Refer to MFS-26128/TN.

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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